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ERRATA.

Page 68, line 4, for " Part 41 " read " Part 48 "

- .. 77, line 13, for " 13·68 " read " 16·46 " and for " 4·28 " read " 4·53 "
- .. 77, 9 lines from end, for " fourth " read " both species "
- .. 90, 6 lines from end, for " upward " read " up-wind "
- .. 218, line 23, for " *Gymnocladius* " read " *Gymnocladus* "
- .. 219, 6 lines from end and p. 226, line 24, for " *Aphanogamus* " read " *Aphanogmus* "
- .. 256, line 1, for " *Stachtarpheta* " read " *Stachytarpheta* "
- .. 257, 11 lines from end, for " T. W. Chorley " read " C. W. Chorley "
- .. 277, line 5, for " *Onix* " read " *Ornix* "
- .. 296, line 25, for " 296 mg." read " 29·6 mg." and " 132 mg." read " 13·2 mg."
- .. 296, line 29, for " some " read " one "
- .. 344, line 2, for " 2° " read " 21° "
- .. 346, 14 lines from end, for " *haptachalca* " read " *heptachalca* "
- .. 361, lines 37, 39, 42, 44, 48, for " cl " read " ci "
- .. 435, line 38, for " *guyava* " read " *guayava* "
- .. 511, 4 lines from end and page 515, 12 lines from end, for " *Helianthemum* " read " *Helianthus* "
- .. 531, line 10, for " 15,935 " read " 19,535 "

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BULLETIN

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FIELD SPRAYING WITH UNDILUTED PARAFFIN EXTRACTS OF
PYRETHRUM AGAINST *ANTESTIA* AND *LYGUS* ON COFFEE IN KENYA.

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1. Introduction.

In a previous paper² the writer described a well known and widely practised method for the control of *Antestia orbitalis*, Westw., var. *lineaticollis*, Stål, by means of a poison-bait applied as a spray, but though at times successful results were obtained with it, the method was uncertain and in some cases dangerous owing to the possibility of destroying valuable parasites and predators of different insects.

Some more certain means of reducing the numbers of this bug in coffee plantations has long been desired, and a new method has been evolved, that of applying an "atomised" spray of undiluted paraffin extract of pyrethrum, which has had considerable success and is here described. The application of such a spray on a field scale, which entails the use of a very small quantity of spray fluid, was first described by the writer in an account of preliminary experiments in the control of the common coffee Capsid bug, *Lygus simonyi*, Reut.,¹ further work on which is now recorded.

2. Methods of Application against Antestia.

The spray used is an extract* of 100 gms. of powder from Kenya-grown pyrethrum flowers in 1 litre of paraffin. It is applied undiluted to the tree with a small hand "atomiser," which may be of an extremely simple and inexpensive type, about 20 cc. of the extract being used for each tree. In order to retain the volatile mist for some time and prevent its being immediately dissipated by the wind, a cover made of cheap cotton cloth (known locally as "americani") is placed over the tree. The usual size of this sheet is 12 ft. by 9 ft., and it is placed so that it hangs lower to leeward than to windward. The spraying is then done from the windward side of the tree. The cover may be removed a few seconds after spraying. It is found that though the bugs mostly fall in the first five or ten minutes, a number may remain hanging in the branches up to half an hour before falling; and of all the bugs that fall a number recover. Half an hour after spraying the tree therefore it is advisable to spray a small quantity of the extract on to the ground. This is an effective means of increasing the ultimate kill.

TABLE I.

No Cover used and Ground not sprayed.

Spray used			No. of trees sprayed	Ccs. per tree	<i>Antestia</i> brought down	<i>Antestia</i> recoveries	Kill of bugs obtained %	
Standard Extract	...	...	3	20	135	41	70	a
Standard Extract	...	...	3	20	82	10	88	b
Proprietary I	...	...	3	20	89	45	50	a
Proprietary II	...	...	3	20	39	13	67	b

The value of this method of field spraying, and its limitations, can be judged by the kills obtained by various methods of application. The technique of these experimental sprayings will be described later. The tables give the results obtained with and without covers and spraying or not spraying on the ground. In the final column the same small letters indicate sprayings which were made at the same time and are in all respects comparable.

* The extract used throughout for experimental purposes is called the Standard Extract. It is standardised in respect of origin of powder (which was grown at the Scott Agricultural Laboratories, Nairobi, Kenya), subsequent treatment of powder, and method of extraction, but facilities for standardisation in respect of pyrethrin content were not available. The variation in toxicity of different samples, ascertained by biological methods, was very small.

If a cover is not used the number of bugs brought down is less, and the recoveries are greater. The percentage kill is only moderate.

TABLE II.

Cover used and Ground not sprayed.

Spray used	No. of trees sprayed	Ccs. per tree	<i>Antestia</i> brought down	<i>Antestia</i> recoveries	Kill of bugs obtained %	
Standard Extract	6	20	138	no record	no record	
	3	20	134	14	90	c
	3	27	50	2	96	d
	3	20	107	9	92	
	4	27	63	10	84	
	2	20	57	2	96	
	3	20	24	3	88	
	9	20	40	5	88	e
	3	13	19	0	100	
	3	20	87	15	83	f
Proprietary I	3	20	35	16	54	g
	5	20	59	13	78	
	3	20	25	9	64	
	3	20	117	39	67	c
	3	27	30	7	77	d
Proprietary II	3	20	79	22	72	f
Proprietary III	4	20	50	20	60	g
Proprietary IV	6	20	38	8	79	e
Kerosene	3	20	0	—	—	

When a cover is used the number of bugs brought down is greater (evidence of the number left on the tree will be given later), and by comparing Tables I and II it will be seen that the use of the cover considerably increases the ultimate kill.

TABLE III.

Cover used and Ground sprayed.

Spray used	No. of trees sprayed	Ccs. on tree	Ccs. per tree on ground	<i>Antestia</i> brought down	<i>Antestia</i> recoveries	Kill of bugs obtained %	
Standard Extract	6	13	7	95	0	100	h
	3	20	7	51	0	100	i
	3	13	7	38	0	100	i
	1	13	7	11	0	100	j
	2	20	7	53	0	100	j
	1	27	7	3	0	100	j
	2	20	7	57	2	96	k
	2	13	7	35	0	100	k
	3	17	3	86	3	97	l
Proprietary I ...	6	13	7	92	4	96	h
Proprietary II ...	3	17	3	51	5	90	l

The Table shows that of 429 bugs brought down with the Standard Extract only five recovered, representing a kill of about 99 per cent.

For completeness the few results obtained without covers and spraying on the ground may be given.

The kill in Table IV is high. The bugs brought down are killed by the spray put on the ground, just as they are when covers are used, the difference is of course in the smaller number brought down.

TABLE IV.

No Cover and Ground sprayed.

Spray used	No. of trees sprayed	Ccs. on tree	Ccs. per tree on ground	<i>Antestia</i> brought down	<i>Antestia</i> recoveries	Kill of bugs obtained %	
Standard Extract	3	17	3	43	0	100	m
Proprietary II ...	3	17	3	24	3	88	m

In Tables II to V the kill has been worked out on the number of bugs brought down by the spray. This is not the kill actually obtained, because it takes no account of the bugs which may be left in the tree which the spray does not bring down. In other tables, unless explicitly stated, the kill is the actual kill, *i.e.*, taking into account all the insects present. The percentage kill is in cases worked out on a very small number of insects, but as the percentage is accompanied by the actual figures there seems little objection to doing this for the sake of uniformity.

In order to ascertain the proportion brought down by the spraying, to the total number present, trees were sprayed a second time and the insects on each application were counted. The results are shown in Table V.

TABLE V.

Standard Extract used with Cover.

Tree	Ccs. per tree 1st application	Bugs brought down 1st application	Minutes elapsing before 2nd application	Ccs. per tree 2nd application	<i>Antestia</i> brought down 2nd application
1	13	22	60	20	0
1	20	23	60	20	3
1	20	43	15	20	2
1	20	31	30	20	0
1	20	31	30	20	1
1	20	82	30	20	3
Total 6		232			9

Out of 241 insects brought down, 232 were brought down by the first application. The percentage left in the above spraying was therefore a little less than four.

In a further experiment a known number of *Antestia* were placed on trees, and these trees were sprayed fifteen or twenty minutes later. The results are shown in Table VI.

This table again shows the value of the cover, and the high proportion of insects brought down. There is, however, the possibility in this case that this proportion

was higher than it would have been under completely natural conditions, because the bugs may not have distributed themselves evenly on the tree in the time given. No spraying on the ground was done in this experiment.

TABLE VI.

Spray	Ccs. per tree	Cover used	No. of <i>Antestia</i> placed on tree	<i>Antestia</i> brought down	<i>Antestia</i> recoveries	Kill %
Standard Extract	20	No	30	26	2	80
Standard Extract	20	Yes	30	29	1	93
Standard Extract	20	Yes	60	60	5	92
Proprietary I	20	Yes	30	26	1	83
Proprietary II	20	Yes	30	25	8	57

The figures show that it should be possible to obtain regularly a kill of about 95 per cent. with this method. In practice, with supervision, and employing the most intelligent native labour available, the kill should not fall much below this.

3. Method of Application against *Lygus*.

In the preliminary experiments against *Lygus*, covers were not used, and several commercial sprayings on a large scale were made without covers. As, however, *Antestia* is nearly always present on coffee as well as *Lygus*, and the kill even of this latter more delicate insect is not so complete without the cover, it seems preferable to use the cover even when the spraying is chiefly against *Lygus*. It should be emphasised here that this spraying is a dual control for both these major pests. Experiments were made chiefly against *Antestia*, because it is a strong bug, difficult to kill, and any spraying method satisfactory against it could be considered without further examination to be satisfactory against *Lygus*.

At a number of different times during experimental sprayings against *Lygus*, using the Standard Extract, with a cover, but without spraying on the ground, the bugs brought down were kept, to ascertain the recoveries. Of 312 insects kept none recovered, and 1 per cent. only was left on the tree. This indicates clearly that the method finally adopted against *Antestia* is even more certainly satisfactory against *Lygus*. An observation of some little importance was made during experimental and commercial sprayings, that almost immediately the *Lygus* were brought to the ground paralysed by the spray, they were seized by ants and carried off. This occurred not rarely, but almost invariably in certain districts. It explains why soon after the spraying it is often difficult to find any *Lygus* under the trees; and it is doubtless of some slight value, particularly with extracts not quite adequately strong.

4. Use of Extract against *Antestia* and *Lygus*.

A few examples will be given of the use of the extract when both *Antestia* and *Lygus* are present together on the trees, which they may be in any proportions. Separately, more than 300 *Lygus* and more than 340 *Antestia* have been recorded on one tree, figures which represent major attacks of the most extreme severity; but the writer considers, from numerous observations under different conditions, that *Antestia* is a major pest when its numbers are above 5 or 6 to a tree, and *Lygus* when above 15 or 20 to a tree. The definition of major pest, as here used, is a pest which causes a real and demonstrable financial loss to the planter. It not infrequently

happens that *Antestia* and *Lygus* are major pests at the same time, and a few examples from trees sprayed at such times with Standard Extract are given, as well as other cases where both insects were present together.

TABLE VII.

			Trees							
			1	2	3	4	5	6	7	8
<i>Lygus</i> brought down	...	...	26	47	56	28	30	48	2	6
<i>Antestia</i> brought down	...	...	5	9	12	12	19	5	20	4

In most of the separate spraying experiments against *Antestia*, a number of *Lygus* were killed, and vice versa. Thus in the sprayings recorded in Table I, 12 *Lygus* were obtained; in Table II, 56 *Lygus* were obtained; in Table III, 3 *Lygus*; and in Table IV, 6 *Lygus*.

The following examples taken from various sprayings against *Antestia* and *Lygus* show the very large number of bugs which may be brought down from one tree by this spray:—

Antestia—343, 157, 138, 133, 122, 125, 123, 177, 177, 156, 147.

With such numbers of *Antestia* the pyrethrum extract spray would always be recommended in preference to the sodium-arsenite bait.

Lygus—303, 100, 162, 206, 101, 114.

With such numbers of *Lygus* the loss of crop would be almost, or quite, complete.

5. Experimental Field Spraying against *Lygus*.

An experiment was planned before the September flowering of 1931, with two chief objects in view. Firstly to determine whether it were possible in practice to keep the numbers of *Lygus* down by periodical sprayings with native labour, and secondly whether the trees would then flower normally. As the experiment was not in this case designed to determine the best times for spraying, but was a preliminary investigation to determine the two points mentioned, the sprayings were many times repeated, and were begun in July, more than two months before the flowering was expected. At this time, being a dry season with no flowering, the bugs were present in small numbers, but a block where there was an average of 8 bugs to a tree, and where at the three previous flowerings there had been a heavy attack, was selected.

In this block a square of 900 trees was selected at random; the 100 central trees were sprayed with covers and the surrounding 800 trees were sprayed at the same times but without covers. These 800 trees were designed as a break to prevent any heavy reinfestation of the central 100 trees which were chiefly observed for results. The whole of the neighbouring coffee acted actually as control, but an adjacent part of the same block was chiefly observed; and 100 trees in this part, selected at random, were taken for direct comparisons with the 100 central sprayed trees. The block was sprayed six times at three-weekly intervals on 2nd and 23rd July, 13th August, 3rd and 24th September, and 14th October. Counts of the numbers of *Lygus* present were made on the dates of spraying and at other times, and the figures obtained are tabulated.

The figures, which were obtained by spraying the trees carefully and counting the bugs which fell on to americani sheets placed under the trees, showed that with three-weekly sprayings the bugs were kept below two to a tree, and usually below one to a

tree, while the numbers in the control block varied from 14 to 30 to a tree. They also showed that five weeks after the last spraying on 14th October, the bugs were still present in small numbers, and that it was not until 8 weeks after the last spraying that, on 10th December, the numbers of bugs were approximately equal on sprayed and unsprayed blocks.

TABLE VIII.

Date	Central 100 sprayed		Surrounding 800 sprayed		Control unsprayed	
	No. of trees tested	Average no. of <i>Lygus</i>	No. of trees tested	Average no. of <i>Lygus</i>	No. of trees tested	Average no. of <i>Lygus</i>
2.vii.*	6	8	—	—	6	8
16.vii.	2	0	—	—	1	19
23.vii.*	8	0.7	5	4.0	—	—
13.viii.*	15	2.0	5	1.2	5	22
3.ix.*	15	0.4	5	1.2	5	26
24.ix.*	15	0.1	5	4.0	5	14
14.x.*	15	0.8	—	—	5	21
5.xi.	5	0.4	—	—	5	30
19.xi.	5	3.6	—	—	5	25
10.xii.	5	29	—	—	5	37

* Block sprayed on these dates.

The spraying was done by native labourers under the writer's supervision. The spray used was the Standard Extract, except on some occasions when a sufficient quantity was not available and a less toxic extract had to be used. Small hand "atomisers" were used. The table shows that by the use of a good pyrethrum-paraffin extract, applied under covers, it is possible to reduce the numbers of *Lygus* to below 2 to a tree by periodic sprayings at three-weekly intervals. This was the first information sought.

The influence on the flowering was studied by making counts of the healthy and damaged flower "spikes," and later when the flowering had set and the berries had grown, by an estimate of the crop on each one of the hundred sprayed and hundred unsprayed trees.

After three sprayings, on 3rd September there was a noticeable difference in the sprayed and the unsprayed block. On this date an examination showed that the numbers of flower spikes aborted in the sprayed block were markedly less than in the control. An odd spike here and there in the sprayed block showed typical *Lygus* damage, but in the control block a whole primary branch often showed damage to some of the spikes at every node. On this date a considerable amount of spike on the sprayed trees was well advanced and promised to flower shortly afterwards. On the unsprayed block this advanced healthy spike was not present. On 10th September there was a small and healthy flowering throughout the sprayed block, while, except for a few blossoms open here and there, there was no flowering on the unsprayed block or on the rest of the estate.

By 22nd September the whole of the Kiambu district had received some rain and flowering was general. On this date both unsprayed and sprayed blocks were flowering, the flowering being heavier on the sprayed than on the unsprayed blocks. Ten trees were selected at random in each block, five secondary branches were taken on each, and ten nodes examined on each secondary. In each case the number of

aborted spikes and the number of fruits set was recorded. The number of apparently healthy spikes was not counted on this date. The figures were :—

250 nodes on sprayed trees, 82 aborted flower spikes, 177 fruits set.

250 nodes on unsprayed trees, 1,088 aborted flower spikes, 36* fruits set.

Of the 100 sprayed trees 90 were in open flower and of the 100 unsprayed trees 47 were in open flower on this date.

On 14th October counts of numbers of aborted and healthy spikes on sprayed and control blocks were made, and the abortion expressed as a percentage of the total. It should be mentioned that this is an uncertain task, and it is not claimed that the figures have great accuracy, but it was thought to be of value to obtain figures for what was so obvious on ocular inspection. A considerable amount of damage had been done a few days before this date by *Locusta migratoria migratorioides*, R. & F.; the locusts had eaten the flowers and bitten into many of the young fruits, which increased the difficulty of examination. One hundred nodes were examined both for aborted and healthy spike in the sprayed block, and fifty nodes similarly in the unsprayed block. The results were :—

Sprayed. Healthy spike and fruit set 2,089, aborted spike 54, i.e., 2·5% of the total was aborted.

Unsprayed. Healthy spike and fruit set 750, aborted spike 518, i.e., 41% of the total was aborted.

These observations at the time of flowering, showing that even when bugs were present in the unsprayed block in numbers not greater than 30 to a tree, a distinct superiority of the sprayed block in respect of undamaged spike was noticeable, and could be expressed in figures, were confirmed later, on 17th February, by a careful estimate of the crop on both blocks, made when the berries were well grown.

These estimates were made by Mr. P. J. H. Coldham, on whose estate the experiment was carried out; his knowledge of the capacity of the trees, and experience in crop estimating, enabled this to be done with considerable accuracy, and the writer is greatly indebted to him for this work, and much other help and advice.

One tree was examined with great care, and used as a basis on which to estimate the crop on the other trees. The crop which had resulted from the short-rains flowerings (September to December) was stripped from this tree and the berries counted. They totalled 9,000 (correct to the nearest hundred) and thus when ripe for picking would have amounted to 1·2 *madebe*.† From previous records on this estate it may be taken that 7,500 berries fill one *debe*, and 525 *madebe* produce one ton of "clean" coffee. This tree therefore, supposing all the coffee reached maturity, would have yielded at the rate of 31 cwt. an acre of 680 trees.

The figure 4 was used as an index to represent this crop, and other index figures from 6 to 0·5 were used to represent the estimated crop on the other trees. The index figures represent direct proportions of crop in the same relation as they are to each other. Thus 6 represents $\frac{6}{4}$ of 1·2 *madebe*, that is 1·8 *madebe* or 47 cwt. an acre; similarly 1 represents 0·3 *madebe* or 8 cwt. an acre. It was found necessary also to use the index 0·5 in estimating for trees carrying some crop but definitely less than 0·3 *madebe*. With 0 representing no crop, or too small a number of berries to consider, there were therefore 8 grades. A difficulty in the comparisons on sprayed and unsprayed blocks was due to the fact that the sprayed trees were carrying more coffee inside along the primary branches right up to the stem, where it is very noticeable that *Lygus* lies up during the heat of the day and when present destroys a large amount of the flower-spike; also at the nodes the number of "cherries" were usually greater

* Of these 36 fruits, 24 were at one node which had happened to flower completely.

† *Debe* (Kiswahili; plural *madebe*) is a petrol tin holding 4 imperial gallons; this is the standard measure for coffee-picking in Kenya.

than on the sprayed trees. In order therefore to check the estimating, one of the trees estimated as grade 4 in the unsprayed block was stripped, and the weight of berries from it proved to be within a few grammes of that of the first tree of grade 4 from which the berries were counted.

It should be mentioned here that from a crop of half to three-quarter grown cherries the tree would certainly shed a proportion before they had ripened fully, the number varying according to the condition of the tree, of the soil and of the season. Therefore the yield per acre calculated would not have been fully realised in practice. Also it should be mentioned that the trees used for this experiment were mostly very fine coffee trees, in all respects in perfect condition for heavy bearing, including the fact that they had had a rest from heavy cropping owing to *Lygus* damage at the three previous flowerings, and in consequence of this the flowering of the unsprayed trees was fairly heavy. As has been shown, there were at no time more than 30 *Lygus* to a tree in this block; while on another part of the estate there were over 100 to a tree. In this part with over 100 bugs to a tree the set of fruit was very small, and had the experiment been carried out there, the effect of spraying would doubtless have been still more evident.

The sum total of all the index numbers representing the estimates of different amounts of crop, the averages and standard errors and other relevant figures are given in the table. One tree was missing in each block.

TABLE IX.

Block	Total of index numbers representing estimates of crop	Mean and standard error.	Difference and standard error of difference	Yield per acre (represented by total of index numbers) in cwt.
Sprayed 99 trees	306	3.1 ± 0.15	1.1 ± 0.19	26.4
Unsprayed 99 trees	202	2.0 ± 0.11		17.3

The figures which show a difference of 1.1 ± 0.19 indicate that there is a significant difference in cropping between the two plots.

The figures represent a yield (supposing all the berries matured) of 26.4 cwt. an acre of sprayed trees, and 17.3 cwt. an acre of unsprayed trees. These yield figures may be compared with the counts of damaged and healthy spikes made on 14th October and recorded previously. On that date 97½% of the flower-spikes were counted to be healthy on the sprayed block, and 59% to be healthy on the unsprayed block. If we take the crop on the sprayed block of 26.4 cwt. an acre to represent the flowering of 97.5% healthy spikes, the flowering of 59% healthy spikes on the unsprayed block should have produced proportionately a crop of 16.0 cwt. an acre. In reality the estimate was 17.3 cwt. an acre, representing only an 8% difference between the crop estimated from the half to three-quarter grown berries and that which might have been expected from the counts of healthy and damaged spikes.

In Table X the frequency distributions of the index numbers representing different estimates of the amount of crop are given.

It will be seen that the heaviest crops, represented by index numbers 6 and 5 (weights of 47 and 39 cwt. an acre) were only recorded on the sprayed block. Such crops could only occur when practically all the flower-spike which was in a condition

to set fruit did so. Also that out of the 99 trees in each block, 44 in the sprayed block and 5 in the unsprayed block produced crop representing one *debe* or more of ripe coffee.

TABLE X.

Index figure for estimated yield	Frequency (<i>i.e.</i> number of trees) in sprayed block	Frequency (<i>i.e.</i> number of trees) in unsprayed block
6	3	0
5	13	0
4	28	5
3	28	37
2	6	26
1	11	15
0.5	4	8
0	6	8

A number of trees in the sprayed block bore a very small crop, because it is inevitable that in any block of 100 trees selected at random a number of them for various reasons (such for example as previous heavy cropping) will not be in a condition to flower heavily. It may be assumed however that such factors are about equal in any two blocks of 100 trees chosen near by in an area of coffee all of one age and similarly manured, pruned and tended, as was the case in this experiment. It has been shown that the crop on the unsprayed block was two-thirds that on the sprayed block, and it is concluded that this difference was due to the difference in the *Lygus* population caused by spraying, because this was the only fundamental difference between the two plots. As the insects were spread fairly uniformly over the unsprayed block, and as the crop on the whole block was two-thirds the potential crop, we may assume that all the trees were damaged by the bugs to the extent of a loss of one-third of the crop on them. It is possible then to examine the condition that would have occurred if each of them had received no damage, by multiplying the crop by $3/2$ and giving them the new appropriate index number to represent the crop thus increased. The distribution thus obtained should theoretically agree closely with the distribution of trees with various crops on the sprayed block, and if there were close agreement it would be additional evidence of the correctness of the conclusion that the decreased yield on the unsprayed block was due to *Lygus* damage spread fairly uniformly over the plot.

Trees in the unsprayed block having index numbers of 0.5, would thus be classified as $0.5 \times 3/2$, *i.e.* 0.75. As this number was not one of the index numbers used in the estimation, it is clear that half such trees would have been classified with the index 0.5 and half with the index 1. In such cases, therefore, as the new value falls midway between two of the index numbers used for the original estimation, half the number of trees having this new value is allocated to each of these original index numbers. The results are shown in fig. 1.

The two curves are closely similar, and there appears therefore to be no doubt that the *Lygus* infestation, spread fairly uniformly over the unsprayed plot, was responsible for the loss of crop on this plot.

Much further evidence that an increase of crop may be effected by spraying when *Lygus* is present was obtained from commercial sprayings. Time was not available for further experimental sprayings such as the one described above.

The method of spraying against *Antestia* entails the following work :—(1) Sweeping out debris from under the tree ; (2) covering the tree with a sheet ; (3) spraying on the tree ; (4) after about half an hour, spraying on the ground.

The actual details of how many boys are necessary for this work, and how they should proceed to do it in the quickest and most effective way, have to be worked out by each planter according to his own views. The sweeping out under the tree at intervals is a counsel of good husbandry, a mulch of leaves under the tree forming a harbour for leaf-miner moth (*Leucoptera coffeella*) and other pests, and the debris is generally better between the rows. It may be considered that just before spraying is a good time for this work.

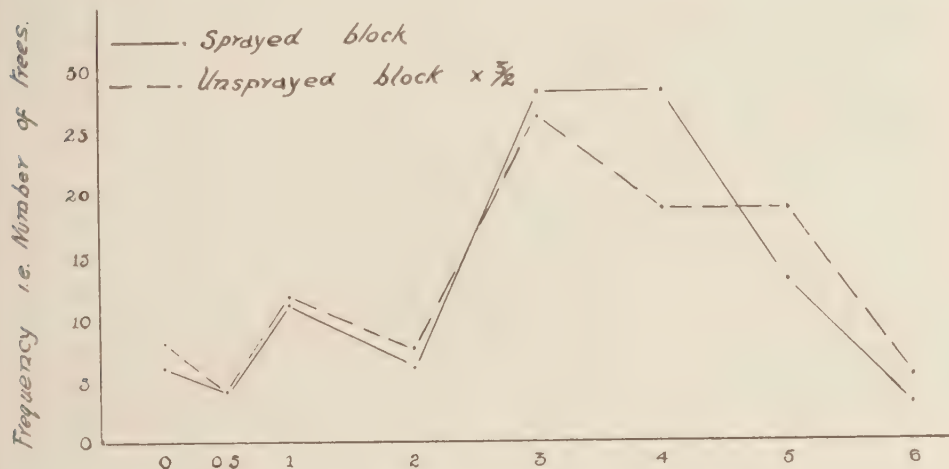


Fig. 1. Index numbers representing estimates of crop.

The writer suggested that each gang of six spraying boys should be supplied with twelve covers, and accompanied by two other boys. These two boys would move the six covers not in use on to six other trees, while the spraying gang were spraying under the other six covers. In this way continuity of work would be possible. This organisation of the work has been used in practice and resulted in the spraying of 150 to 160 trees per "boy-day," including those boys employed in mixing and carrying spray. Some planters have preferred to have two boys to one pump and one cover; some slight capital expense in the provision of covers is saved, and two boys taking turns with the pump are able to keep up a high rate of work, so that it has been found possible thus to spray 350 trees per pump per day. Counting those boys mixing and carrying spray, 160 to 170 trees may be sprayed by this organisation per boy-day.

Various modifications of these routines have been used by planters according to their desires, and the number of trees sprayed per boy-day has varied from 100 to 180, depending on the size of the trees and the organisation of the work. In spraying against *Antestia* some planters have preferred to have children collecting the *Antestia* when they fall rather than spraying on the ground. This was found to be necessary in certain cases when planters were not able to obtain a spray of adequate toxicity. One child can collect in one day under the trees sprayed by one boy and five children can collect under trees on one acre; the cost of this is 1 sh. 50 cents.* As it is probably almost as effective a method of obtaining the *Antestia* which are brought down and the cost is less than that of spraying on the ground, it may be recommended for practical applications.

*100 cents = 1 East African Shilling = 1 shilling sterling.

6. Experimental Technique.

The field testing of the sprays the results of which are summarised in the Tables was carried out with as much precision as possible, and it is believed that the figures obtained in these experiments are of more value than the approximations it is usually possible to obtain in field sprayings.

In all cases where there was no special application of spray to be made on the ground, large cotton (american) sheets were placed under the trees, and the insects were collected from the sheets as they fell, placed in large cardboard boxes and soon afterwards transferred to wire gauze cages containing fresh coffee shoots, in which cages the recoveries were counted. In every case where the ground was sprayed, the leaves and debris were swept out from under the trees and after the spraying on the tree and ground was finished, the insects were carefully sought and transferred to the gauze cages as before.

With sprays diluted in water, the ground-sheets were again used. As soon as the spraying was complete, if any insects had come down they were collected, the sheets were removed and dry sheets substituted. The insects were then carefully and quickly collected as soon as they fell.

In a number of cases after spraying with paraffin extracts, and water-sprays, the tree was sprayed a second time with paraffin extract in order to determine the number of insects left on the tree after the first spraying. As the time during which the insects fall from the tree may be as much as thirty minutes after spraying with a paraffin extract, and ninety minutes after spraying with a water-spray, it will be realised that these field sprayings entail much labour, and that only a very limited number of trees can be carefully treated in this manner in a day. The experimental side of this investigation entailed sixty days spraying in the field. The writer however believes that figures carefully obtained in this manner, even from a few trees, are of real value. The paraffin-pyrethrum extract spraying will also make it possible to obtain similar accurate data in field sprayings against different bugs on other crops, and should enable a more certain knowledge of the action in the field of different insecticides to be obtained than in the past.

Laboratory tests with different extracts and water-sprays are valueless alone as an indication of what the spray will do in practice. Thus an extract of 25 gms. of powder in a litre of paraffin causes 100 per cent. mortality of *Antestia*, lightly sprayed in the laboratory, while it is useless when applied in practice. Once however a thorough knowledge is obtained of the effect of one of these sprays in the field, laboratory comparisons of other sprays with this standard spray are completely adequate, and make it unnecessary to test these other sprays laboriously in the field. In this investigation, as has been recorded, a method was designed capable of giving an almost complete kill of *Antestia* in the field, with a Standard Extract of 100 gms. pyrethrum powder in 1 litre of paraffin. A laboratory technique, to be described later, which enabled a comparison to be made of the toxicity of any similar spray with the Standard was evolved. By this means it was possible to determine the proportion of powder and paraffin necessary to make an extract equal in toxicity to the Standard (and so of adequate toxicity for control of bugs in the field), to determine the dilution necessary with a concentrated extract, or to ascertain the probable efficiency in the field of an extract ready prepared.

The recoveries in the gauze cage were determined two days after spraying. A proportion of the bugs which had appeared paralysed were found to recover up to two days after the spraying, and similarly other bugs did not die or become moribund until two days after. Recoveries were not seen to occur after two days, but on the other hand, of unsprayed *Antestia* placed in similar gauze cages, deaths began to occur after the second day. It is considered that counts of the recoveries on the second day are of fair accuracy, and are in fact as accurate as it is possible to obtain.

Only those bugs which could walk were counted as recoveries; those capable only of aimless movements of the appendages (moribund) the writer, in common with other workers, classed with the dead insects.

As of course there were no pumps designed for applying this spray on a field scale, several types of pump used for other purposes were tried, of which possibly the simplest type of small hand "atomiser," costing two shillings or less and used for applying mosquito sprays in houses, was the most satisfactory. Certain types of these expel a minute quantity of liquid by each stroke of the piston, which means that a large number of strokes may be applied to each tree, thus ensuring that all parts of the tree receive some of the atomised spray. The number of piston strokes can be used as an indication of the volume of spray applied. With the small hand-atomiser used in the majority of the above experiments, between 76 and 78 strokes expelled 20 cc., which volume applied to each tree equals an application of 3 gallons an acre of 680 trees. Such a pump is preferable to a larger one expelling more liquid by each piston stroke.

It is not considered however that these sprayers are completely adapted to the purpose. An apparatus with which excellent results were obtained was one designed for spraying paint, and used for applying the finish to motor cars. In this type, of which the essential principle is the same as with the small sprayers, the nozzles are adjustable, one is horizontal and connected with a pump and container for compressed air, the other is vertical and connected by a tube with a container of liquid. The blast of air from the horizontal nozzle draws spray up the tube and delivers it as a very fine mist. With this apparatus the container used was a measuring cylinder, and any exact volume of spray could be delivered, or the volume necessary for different trees according to their size could be read off. With this sprayer it was possible to obtain similar results with a somewhat smaller quantity of spray than with the hand sprayer.

A design for a simple sprayer similar to the small hand-atomisers, but stronger, and with a gauge by which the amount suited to the trees could be read off, has been prepared, and it is hoped to have this made when opportunity permits.

7. Foliage Injury by Kerosenes.

In the application of an undiluted paraffin spray to the coffee tree, the question of foliage injury is of primary importance. Following the large amount of recent chemical work on this question, particularly in California, it should be possible to obtain an oil exactly adapted for this spraying, and one which would have practically no injurious effect on foliage. For this spraying, however, an oil was required immediately in large quantities, and the different proprietary kerosenes available in the country were the only oils which could be used, and they had immediately to be examined. It early appeared that certain of these kerosenes caused considerably more foliage injury than others, and that some were quite unsuited for application direct to coffee foliage, even in the small quantities and fine mist required for this form of spraying.

It has been shown by Gray & De Ong³ that with certain petroleum distillates the constituents that chiefly cause foliage injury are the unsaturated hydrocarbons of the olefine series, the aromatic hydrocarbons and sulphur derivatives of the hydrocarbons, in short the constituents that are removed by the refining process of sulphonation. This is the treatment of the oil with sulphuric acid or liquid sulphur dioxide which converts these unsaturated constituents into sulphonates which can then be removed from the oil. It is known that certain kerosenes prepared for lighting purposes are refined by such a method in order to reduce their tendency to smoke, and a number of experiments were made with various proprietary kerosenes to determine whether the kerosenes which were known to be highly refined in this way were in practice the least likely to cause scorching.

It was shown immediately that the "power" kerosenes, used in tractor engines, all scorched very severely, while the "lighting" kerosenes on the whole scorched much less severely. Of the lighting kerosenes used, the two that caused markedly less scorching than the others were oils which had been highly refined by sulphonation. The presence of the unsaturated hydrocarbons directly influences the smoke production of the kerosene when burned, and the tendency to produce smoke is measured by certain oil companies and called the T.T.S. (tendency to smoke) factor. Knowledge of this factor therefore is of use when a kerosene has to be sought for this purpose of direct application to coffee. A low T.T.S. is thus at least a useful indication of the tendency of an oil to scorch. Once a proprietary oil has been found satisfactory it is necessary to be certain that the constitution of successive samples of the oil remains fundamentally unchanged, and therefore frequent tests on the growing plant are advisable.

In order to determine whether a test of the scorching properties of a kerosene could be readily and sufficiently accurately made on growing coffee foliage, a small experiment was planned. Two kerosenes were mixed in varying proportions, the first (S) a highly refined lighting kerosene with a very low T.T.S. factor, the other (B) a power kerosene known to contain a very high proportion of unsaturated hydrocarbons. Twenty leaves were sprayed with each of the mixtures and the percentage area of the leaves scorched was calculated four days later by determining the area uninjured and injured with a photograph of graph paper, on glass.

TABLE XI.

Oil'	% scorched of total area of leaves
S	1
S + 5% B	3
S + 10% B	4
S + 20% B	15
S + 40% B	30
S + 50% B	33
B	45

The fact that there is an increase in scorch with each increase in the proportion of the kerosene with a high aromatic content, indicates that it is possible to ascertain with sufficient accuracy the liability of any kerosene to scorch foliage by such a trial on the growing plant.

A field trial of a number of proprietary lighting kerosenes was made on 20 trees. A shoot on each tree was dipped into a beaker containing in turn each of the kerosenes tested. The scorch resulting was estimated four days later, and arbitrary numbers from 0 to 6, representing different degrees of scorch from "very severe scorch," which included marked scorching of the shoot as well as of the leaves, to "no visible scorch," were allocated. The sum totals of these index figures for each oil are given in Table XII, and the T.T.S. factor of the oil is also recorded.

The figures examined in detail show a significant difference between two groups of lighting kerosenes, the first group containing only two kerosenes, each with the low T.T.S. factor of 1, while the second group contains all the other lighting kerosenes, the differences between which, on the figures obtained, are not significant.

On the second occasion, the two kerosenes with T.T.S. factor 1 proved to compare almost exactly as they had on the first occasion. It appears that the method of comparison is sufficiently accurate for the practical purpose of selecting an oil for field spraying, and in the last column their classification for this purpose is given

As was to be expected, in very sunny hot weather the kerosenes all caused more severe scorching than in cool dull weather. This is shown by the increase of scorch of the first two kerosenes in the table in October 1931 over that caused in August. The tests were made in August with a sky overcast during most of the four days of the test; in October the sun was very much fiercer. In practice, however, if a highly refined kerosene be used and applied in the small quantities necessary in this form of spraying, no damage to the tree is caused, in any conditions of weather. If larger quantities of neat paraffin, of no matter what constitution, were applied, there is no doubt that its action on the tree would be deleterious, but with applications of 15 to 30 cc. per tree a large area of the foliage does not receive any of the oil, and thus even repeated applications do not appear to be dangerous. The six applications at three-weekly intervals described in Section 5 had no noticeable effect on the trees. With lighting kerosenes, however, of a high T.T.S. factor, tips of shoots may be burned even by this spraying, and a careless boy may produce a noticeable amount of damage.

TABLE XII.

Kerosene	T.T.S. factor	Index representing scorch on 20 shoots		Practical classification
		Aug. 1931	Oct. 1931	
Lighting { 1 ...	1	62	39	} Slight scorching
	2 ...	62	40	
Lighting { 3 ...	6	40	—	} Medium scorching
	4 ...	46	—	
	5 ...	42	—	
	6 ...	—	10	
	7 ...	—	15	
Power { 1 ...	—	0	0	} Severe scorching
	2 ...	0	0	
	3 ...	0	0	

The physiological condition of the tree also influences the scorching; some evidence was obtained in this work that debilitated trees suffered more severely from kerosene scorching than healthy trees. Such influences are of more theoretical than practical interest and they were not fully investigated.

8. Laboratory Comparisons of the Toxicity of Pyrethrum Extract Sprays.

As soon as paraffin extracts of pyrethrum came to be used in the field for the control of *Lygus simonyi* and *Antestia*, it was found necessary to have some fairly rapid method of comparing the toxicity of different sprays of this type. To make adequate tests of their toxicity in the field would have been extremely laborious and at certain times, when insects were not present in large numbers on the coffee, would have been impossible.

Percentage mortalities of insects sprayed with extracts of different strengths were not satisfactory, because the ultimate death of the majority of insects sprayed with these extracts caused an undue approximation of the results obtained. Thus in some cases an extract only one-quarter the strength necessary for the successful field control of *Antestia* would eventually achieve 100 per cent. mortality in the laboratory.

It appeared possible that comparisons of extracts might be made on the basis of the time taken to kill the insects. As the exact time of death, however, is impossible to ascertain, the times taken to paralyse the insects proved to be a satisfactory index for comparisons. In the case of *Antestia orbitalis* var. *lineaticollis*, the insect used in these tests, it is possible, with some practice, to judge the moment of paralysis fairly accurately.

As the Standard Extract produces about 100 per cent. kill of *Antestia* in the field, tests of all the other powders and extracts were comparisons with it, or in certain cases with specific dilutions of it. A sufficient number of adult *Antestia* to give results statistically significant were sprayed separately with the Standard Extract and with the extract under trial, and the time taken to produce paralysis of each insect was observed. From experiments with the Standard Extract of 100 gms. per litre, and extracts of the same powder at 75 gms. per litre, it was shown that a significant result could be obtained by spraying 25 *Antestia* with each of the extracts. In this way an extract of 100 gms. per litre could be shown to have a significantly higher toxicity than one of 75 gms. per litre. By comparing any extract at different dilutions with the Standard Extract it was possible to ascertain the dilution necessary to ensure equal results.

After this biological method had been in use for some time, the account by Richardson⁴ of the evaluation of household insecticides of the same type, in which the time of paralysis of flies was the index, was received.

The first results were obtained by spraying the *Antestia* separately with a small "nasal" sprayer. By this means it was not possible to arrange that each insect received an exactly equal quantity of the spray, and the paralysis time for different individuals sprayed with the same extract varied fairly widely. But by using a sufficient number of insects, even with this method, it was possible to obtain results which showed a significant difference between extracts of 100 gms. and 75 gms. powder per litre. Later an apparatus based on that of Tattersfield & Morris⁵ but considerably simplified, designed by Mr. V. A. Beckley, the Senior Agricultural Chemist, was used. When using this apparatus the chief source of variation was in the resistance of the insects themselves, as no particular precautions could be taken in these experiments to reduce this variation.

In the table which follows are given the results of comparisons of the Standard Extract and dilutions of it.

TABLE XIII.

Extract		No. of insects sprayed	Mean paralysis time in half-minutes and standard error	Difference between means and standard error of difference	
100 gms. per litre	...	175	11.0 ± 0.13	}	...
75 " "	...	70	13.0 ± 0.25		
50 " "	...	50	15.3 ± 0.34		
25 " "	...	30	19.8 ± 0.78		
					2.0 ± 0.28
					2.3 ± 0.42
					4.5 ± 0.85

The use of paralysis time data, rather than mortality data, is likely to be of general value, when comparisons of similar sprays all containing the same poison are necessary.

It should be mentioned here that most of the powders, extracts and ready-mixed sprays, proved to be considerably less toxic than the Standard Extract used in these experiments. This not only lessened the value of the method for commercial use,

but also in the beginning caused planters considerable doubts as to the value of this form of spraying. On the other hand, to show that a spray of higher toxicity could be prepared by the planter himself, using very simple methods from locally grown pyrethrum powder, than was supplied often at a considerably greater cost by commercial firms, was of great value. It suggests that by growing his own pyrethrum the planter will always have ready a cheap and most effective insecticide.

The pyrethrin contents of samples of the powder used in preparing the Standard Extract were determined by Dr. Tattersfield and Mr. J. T. Martin at Rothamsted, and the writer owes them thanks for their help in this respect. Two samples contained 1.44% and 1.08% total pyrethrins respectively; and a third sample, of which the pyrethrin I content alone was determined, proved to contain 0.67% pyrethrin I. Such values are in the neighbourhood of three times the average values of commercial powders (see Fryer & Gimingham⁶).

That the biological and chemical results obtained independently agree in indicating the superiority, and about the same measure of superiority, of the local powder over many commercial powders is a point of considerable interest and importance. It affords additional evidence that the practical, and hence the commercial, value of pyrethrum powder can be satisfactorily ascertained by a determination of the pyrethrin content.

This investigation has shown very clearly that the present position of the pyrethrum market is most unsatisfactory. Pyrethrum powders which vary in toxicity by at least as much as 300 per cent., are sold with no indication of such differences, on which their value depends. The consumer has no guide as to how much of the powder he should use for his special purposes, and no certainty that he is obtaining an article of value for his money.

Some accurate expression of the toxicity of all pyrethrum powder marketed, enabling the consumer in any part of the world to know the value of the article, is clearly essential. The figure which expresses the toxicity must be obtained by some uniform, comparatively simple method, which it is possible to carry out in all parts of the world where the powder is used. Of the two different classes of methods for ascertaining the value of pyrethrum powder, the biological and the chemical, only the chemical fulfils these conditions. Biological tests may ascertain the toxicity of a powder to a certain insect in certain conditions, but while they are completely adequate for a comparison of different powders in any one place and time, the conditions of the tests cannot be reproduced in different parts of the world, nor in the same part at different times, and so no valid figures expressing the toxicity of commercial powders can be obtained from biological tests. For example, the fact that a powder may be 75% effective against the house-fly in America, or against the cockroach in England, is no indication of its possible value against *Antestia* in Kenya.

Evidence has now accumulated that the toxicity of pyrethrum powder is measured with considerable accuracy by a determination of its pyrethrin content, and on this account, for the protection of both the consumer and the producer it would be of advantage if all commercial powders were marketed with a declaration of the pyrethrin content, as determined by a uniform chemical method.

From the determinations of pyrethrin contents of the powders used in these experiments, it is possible to suggest tentatively a formula for the preparation of a spray of adequate toxicity for the field control of *Antestia*, and hence of a large number of other insects of equal or lower resistance to pyrethrum. One hundred grammes of powder are extracted in one litre of paraffin, and from the figures 1.44% and 1.08% total pyrethrins, it seems probable that a correct spray could be prepared from 100 gms. of powder with a content between 1% and 1.5% total pyrethrins.

For the present we may take the mean 1.25% as the figure. The number of grammes of powder of any known pyrethrin content which it is necessary to extract in 1 litre of paraffin may therefore be obtained from the formula :—

Number of grammes of powder, multiplied by Index number representing percentage of total pyrethrins, equals 125.

Thus with a powder of 1% total pyrethrins, which is probably as high as it is possible to obtain with any regularity on the market, 125 gms. of powder are necessary, and with a powder of 0.5% total pyrethrins 250 gms. must be extracted.

It is possible that future work will enable a more accurate recommendation to be made.

9. Preparation of Paraffin Extracts of Pyrethrum.

In the first experiments the spray was prepared by shaking up the powder and paraffin together at intervals, over a period of one, two or three days, and filtering the mixture to give a clear extract for spraying. The great toxicity of the extract prepared by this simple method was its justification, because it is evident that if an efficient spray may be prepared simply and inexpensively by planters, it has on that account alone an advantage over more costly sprays prepared by commercial firms.

A superior method of preparing the spray, suggested by Mr. V. A. Beckley, was afterwards employed. A large drum was used, in the bottom of which holes had been bored; a tight layer of cotton-wool was packed over the holes, and the pyrethrum powder placed on top of the cotton-wool. The requisite volume of paraffin was then passed through the powder and filter thus made. By packing the cotton-wool correctly it was possible to ensure that the paraffin percolated very slowly into the receptacle below and a strong filtered extract was thus prepared. This method was used in the preparation of the Standard Extract. By arranging a series of such filters and passing the paraffin for a new extraction through drums of pyrethrum already used, it is possible to maintain a steady supply of the insecticide and to extract almost to the total value from the powder. This was found to be the most satisfactory method of extraction by the planter, and entailed a minimum of work and supervision.

10. Value of the Pyrethrum Extract Spray to determine the Number of Insects on the Trees.

In addition to the value of this spraying as a commercial control for *Antestia* and *Lygus*, it is of great use in enabling the planter to discover rapidly how many insects are present on the trees. Formerly only an estimate of the number of insects present was possible, and only the grossest differences in the numbers present could be observed. It was found also that the number present was nearly always much underestimated. By means of this spraying, using americani sheets on the ground, the numbers of *Antestia* and *Lygus* can be readily obtained. Ten trees selected at random may generally be taken to give an adequate idea of the infestation in a block. This enables the planter to decide when and where he should spray, and also enables him to discover the actual result of his spraying by comparing the number of bugs present before and after.

It should also be of great value to the entomologist, in ecological studies of these or other insects on coffee and other crops, to be able to obtain accurate data on the numbers of insects present. Especially is its value evident in obtaining accurate figures in nearly all forms of experiments with insecticides, and it is likely to be used for this purpose in the future.

11. Effect of Spraying on the general Fauna of the Tree.

A very large number of diverse insects which may be present on the tree are killed by the spray. No particular study of these insects has been made during

this investigation, so it has not been completely determined whether, apart from the *Antestia* and *Lygus*, the spray destroys more harmful or more beneficial insects. The following observations however bear on this question.

The spray, applied as it is in the form of a light mist, is of course useless against mealybugs and scales, a minute proportion only being killed by it. On the other hand a large proportion of the Coccinellid and other predators of *Pseudococcus lilacinus* and other insects are killed. Where *P. lilacinus* is a major pest, and it is known that it is being controlled by predators, it is probably not advisable to use this spray. In other cases, where the mealybug is potentially serious, the actual severity of the *Lygus* or *Antestia* infestation must be the deciding factor. If this infestation is slight it will probably be advisable not to spray; but if severe, the risk of an increase in the mealybug infestation, due to killing the predators by the spray, must be taken. In practice the spray has been applied in several cases over large areas where mealybug is potentially a very serious pest, and up to the present the writer is aware of no increase in mealybug which could be considered as due to the spraying.

In various sprayings the following insects, in addition to *Antestia* and *Lygus*, have been killed. They may be classified in three columns thus :—

Beneficial or probably beneficial	Injurious or probably injurious	Probably neither beneficial nor injurious
Coccinellidae (many species)	Lepidoptera <i>Odites artigena</i> (larvae killed)	Diptera (very many species)
Hymenopterous parasites (many species)	<i>Porthesia aethiopica</i> (larvae killed)	Coleoptera (several species)
Tachinid parasites (two or more species)	<i>Epigynopteryx ansorgei</i> (larvae killed)	Blattidae
Syrphidae	<i>Leucoptera coffeella</i> (imagines killed)	Collembola
<i>Geocoris rufipes</i> (predacious on <i>Lygus</i> <i>simonyi</i> and other in- sects)	<i>Thliptoceras octoguttalis</i> (imagines killed)	Spiders (many species)
Mantidae (several species)	<i>Eucosma nereidopa</i> (imagines killed)	
Psocidae	and others	
Thysanoptera (carnivorous species)	Coleoptera <i>Systates</i> sp. and others <i>Sophronica ventralis</i>	
	Capsidae (2 species)	
	<i>Dieuches armipes</i>	
	<i>Agonoscelis</i> sp.	
	Fulgoridae (2 species)	
	<i>Jubella bellicosa</i>	
	Formicoidea (several species)	
	Isoptera	
	Thysanoptera (phytophagous species)	

In one spraying of 20 trees the following insects were killed. The "bag" obtained varies greatly from plantation to plantation, and from time to time, but neither in variety nor in numbers of insects is this list in any way exceptional:—

<i>Antestia orbitalis</i> var. <i>lineaticollis</i>	...	...	...	182
<i>Lygus simonyi</i>	...	...	...	1
<i>Geocoris rufipes</i>	...	...	...	4
<i>Dieuches armipes</i>	...	...	...	1
<i>Jubella bellicosa</i>	...	...	...	1
Fulgoridae (2 species)	...	...	...	4
<i>Odites artigena</i> (larvae)	...	...	...	about 200
Elateridae	...	...	...	2
<i>Systates</i> sp.	...	...	...	1
Coleoptera (other)	...	...	...	several
Diptera	...	...	...	many
Formicoidea	...	...	...	several
Parasitic Hymenoptera	...	...	...	several
Mantidae	...	...	...	1
Blattidae	...	...	...	2
Spiders	...	...	...	about 30

The number of insects killed by this spray comprises only those that are on the tree at the moment of spraying, and so is not likely to be so large as when using a poison-bait which exerts an attraction for a considerable time and obviously draws insects from sheltered situations. With Hymenopterous parasites, for example, it may well prove that the number killed in a spraying with pyrethrum extract of the coffee trees on a whole plantation does not represent a very large proportion of the total number present on the plantation.

With the exception of the special cases of mealybug discussed, it appears at present that there is little danger of a serious increase of another pest being induced by this spraying. What injurious effect it may have in this direction, is doubtless usually compensated for by the beneficial influence it has in killing other injurious insects in addition to *Antestia* and *Lygus simonyi*.

12. Probable wider Utility of Pyrethrum-Paraffin Extracts for Field Spraying.

Planters in Kenya very quickly realised that this was a contact insecticide that might be applied commercially. Up to the present, control of insect pests of coffee by contact spraying has not been general, the few attempts to control insects by the application of contact sprays in water were early given up, owing to their expense. In the 12 months, however, following the first experiments with this extract spraying, it is estimated that between 20,000 and 30,000 gallons of spray were applied, representing the spraying of 7,000 to 10,000 acres of coffee.

The results obtained with this spray on coffee therefore suggests that it has a much wider field of utility. It seems certain that on many other crops where similar insects are at present controlled by expensive contact washes, the economy of destroying them with so little labour and the use of such a comparatively minute volume of spray fluid will be evident.

13. Other Plant Poisons extracted in Paraffin.

Attempts to extract the toxic principles of *Cracca* (*Tephrosia*) *vogelii* and tobacco, in paraffin, in a similar simple manner such as could be used on the plantation, were made. It was found that the extracts prepared from 400 gms. of *Cracca* leaves

and from 500 gms. of pulverised tobacco, each in 1 litre of paraffin, were only slightly toxic. A fairly large proportion of the insects present were brought down from the trees, but a very large percentage recovered. Laboratory trials showed that the extracts prepared from *Cracca* and tobacco, although they were not completely lacking in insecticidal properties, were so much inferior to the pyrethrum extract as to be hardly comparable by the methods used.

There seems however to be a field for further work in the extraction of such poisons by more efficient methods, and their incorporation in paraffin for this form of spraying. Either of the above plants would yield in Kenya a far greater weight per acre of material containing the insecticidal principles than does *Chrysanthemum cinerarifolium*.

14. Comparison of Pyrethrum-Paraffin Extract with a Spray diluted in Water.

It should be mentioned here that the application of this pyrethrum extract is a form of contact spraying. The spray kills only on contact, and although in its state of fine division in the form of minute paraffin droplets bearing the toxic principles of the pyrethrum flowers, a comparatively minute quantity of spray is efficient, there is no reason to suppose that it acts in any way as a fumigant. The "atomised" spray of the moderately volatile paraffin does however partly simulate a fumigant, in that it hangs about under the cover for some moments in a kind of light cloud, and it penetrates to all parts of the tree, even between the flower buds, more as a gas would.

The chief value of this spraying with a neat paraffin extract, therefore, lies in the minute quantity of spray necessary. It is the only contact insecticide that has come to be widely used on coffee in Kenya, and this is because it is recognised as being incomparably cheaper and less troublesome to apply than any water spray.

One small experiment designed to compare the volume of spray fluid necessary for equivalent results with a water spray and the paraffin-extract was carried out.

Trees were sprayed with a proprietary pyrethrum emulsion at the strength recommended for the control of CAPSIDAE, at the rate of $\frac{1}{2}$ gallon, 1 gallon, and 2 gallons to a tree. The extract of 75 gms. pyrethrum in 1 litre paraffin ($\frac{3}{4}$ strength) was applied at the rate of 0.006 gallons to a tree. Both *Antestia* and *Lygus* were present on the trees. Ninety minutes after spraying with the water spray, and 30 minutes after applying the pyrethrum paraffin extract the trees were all sprayed with the pyrethrum extract to determine the number of bugs left on the tree. The possibility that $1\frac{1}{2}$ hours was not long enough for the water spray to produce its total effect is not excluded, but as a number of bugs brought down in this time afterwards recovered completely, it is reasonable to suppose that of the bugs which may have been hit but not brought down the recovery would have been very high. The following table gives the results of this experiment. In two cases the numbers of *Antestia* on the trees were considered to be too small to calculate percentage kills, even though the actual figures are appended (Table XIV) on which these might be based.

The trees were large and fairly thick in foliage and the table shows that even after the application of as large a volume of spray as 2 gallons a tree, a number of insects may be left, and that $\frac{1}{2}$ gallon or 1 gallon a tree is quite inadequate. The pyrethrum extract at 4 gallons an acre was preferable to the water spray both in the proportion of insects brought down, and the kill. Had the extract been of the standard strength (100 gms. to a litre) the kill would have been still higher.

It is possible then to compare the costs of the two methods. The cost of spray fluid for one acre with the water-spray at 2 gallons a tree is 90 sh.; the cost of

the pyrethrum extract used for one acre is 10 sh. The total cost of application (labour and spray) with the water-spray may be estimated at 100 sh., and with the pyrethrum extract at 12 sh. an acre.

TABLE XIV.

Date of spraying	Spray	No. of trees sprayed	Volume of spray per tree in galls.	Insects obtained		Recoveries		Insects obtained by 2nd application		Kill per cent.	
				<i>An-testia</i>	<i>Lygus</i>	<i>An-testia</i>	<i>Lygus</i>	<i>An-testia</i>	<i>Lygus</i>	<i>An-testia</i>	<i>Lygus</i>
10.xi.31	Pyrethrum concentrate in water 1 : 1,280 ...	2	0.5	1	17	1	4	7	14	—	42
11.xi.31	Pyrethrum concentrate in water 1 : 1,280 ...	2	1.0	11	25	5	4	5	7	38	66
10.xi.31	Pyrethrum concentrate in water 1 : 1,280 ...	2	2.0	20	83	5	11	3	6	65	81
12.xi.31	Pyrethrum powder in paraffin, 75 gms. per litre ...	2	0.006*	3	40	1	2	1	1	—	93

* Equivalent to 4 gallons an acre.

15. Bordeaux Mixture and Pyrethrum, a combined Fungicide and Insecticide.

From the comparative figures given of the costs of a water spray and the pyrethrum paraffin extract, it is clear that the latter spray, where it is proved effective, will be employed in preference to the former.

It sometimes occurs that a spraying with Bordeaux mixture against leaf disease (*Hemeleia*) has to be undertaken. As in such a case a water spray has to be applied, it appeared that it might be possible to incorporate an insecticide with it and so save separate applications.

The following insecticides were tried with the Bordeaux :—(1) a proprietary concentrated extract of pyrethrum ready prepared for dilution in water ; (2) the Standard Extract of 100 gms. local pyrethrum powder in 1 litre paraffin emulsified by the addition of a proprietary calcium caseinate emulsifier and spreader ; (3) pyrethrum powder ; and (4) a proprietary extract of derris, ready prepared for dilution in water.

The first of these insecticides mixed satisfactorily with the Bordeaux, and was also applied in water alone, as recommended. The second, the paraffin extract, mixed satisfactorily by the use of the emulsifier. The third, pyrethrum powder, was first soaked overnight in water and then incorporated in the Bordeaux ; later the powder was mixed with the Bordeaux without any previous soaking. The derris extract mixed satisfactorily with the Bordeaux.

The Bordeaux used in this case was in a form often used in Kenya for commercial spraying against leaf disease. Its constituents are :—Copper sulphate 2 lb., calcium carbide 12 oz., water 40 gallons.

After the first application the number of bugs left on the tree was ascertained, as before, by spraying thoroughly with pyrethrum paraffin extract.

The results of the trials are given in the table.

TABLE XV.

Spray	No. of trees sprayed	Gallons per tree	<i>Lygus</i> obtained	<i>Lygus</i> recoveries	<i>Lygus</i> obtained 2nd application	Kill per cent.	Approximate cost per acre of insecticidal materials
Proprietary pyrethrum concentrated extract 1 : 1,280 water ...	2	1½	44	10	2	74	45/-
Proprietary pyrethrum concentrated extract 1 : 1,280 Bordeaux	2	1½	41	2	4	87	45/-
Proprietary Derris concentrated extract 1 : 800 Bordeaux ...	2	1½	14	0	20	41	38/-
Standard pyrethrum paraffin extract 1 : 20 Bordeaux + spreader ...	1	1	21	0	0	100	58/-*
Pyrethrum powder 1 lb. : 20 galls. Bordeaux ...	4	1	66	0	4	94	50/-*
Pyrethrum powder 1 lb. : 40 galls. Bordeaux ...	4	1	127	0	11	92	25/-*
Bordeaux ...	6	1	1	1	100	0	0

*Pyrethrum powder reckoned at 1s. 50 cents a pound.

The trees sprayed were well pruned and fairly open, and therefore one gallon of spray was almost adequate for insecticidal purposes. The table shows clearly that the addition of pyrethrum, whether by simply mixing the powder into the Bordeaux or by emulsifying a paraffin extract, makes the resultant mixture an effective insecticide.

In an attempt to determine whether there was any action between the pyrethrum powder and any one of the constituents of the Bordeaux, which might influence its toxicity, the different constituents were mixed separately with pyrethrum powder and the resulting mixtures tested in the laboratory and in the field. The formula for the Bordeaux mixture in this case was :—Copper sulphate 5 lb., lime (hydrated) 7 lb., proprietary calcium caseinate spreader 1 lb., water 100 gallons. The pyrethrum powder was added in each case at the rate of 2½ lb. to 100 gallons.

In the laboratory 30 *Antestia* were sprayed with each liquid, using a nasal sprayer, 10 of these separately one at a time, the remaining 20 in two batches of 10, complete wetting being obtained. The results of the laboratory tests are given in the following table :—

TABLE XVI.

Spray	<i>Antestia</i> sprayed	<i>Antestia</i> recoveries
Bordeaux	30	25
Bordeaux + pyrethrum	30	6
Lime + spreader	30	24
Lime + spreader + pyrethrum	30	2
CuSO ₄ + spreader	30	28
CuSO ₄ + spreader + pyrethrum	30	4
Spreader	30	22
Spreader + pyrethrum	30	0
Water	30	24
Water + pyrethrum	30	1
Total Bordeaux, etc.	150	123
Total Bordeaux, etc. + pyrethrum	150	13

In the field 1 gallon a tree was applied in each case, at a pressure of 80 lb. to a square inch. The results are given in the table:—

TABLE XVII.

Spray	No. of trees sprayed	<i>Antestia</i> obtained	<i>Antestia</i> recov- eries	<i>Antestia</i> obtained 2nd applica- tion	Kill per cent.
Bordeaux + spreader	2	3	2	24	4
Bordeaux + spreader + pyrethrum	2	14	0	5	74
Lime + spreader	1	0	—	25	0
Lime + spreader + pyrethrum	1	22	2	6	71
Spreader	1	0	—	18	0
Spreader + pyrethrum	1	16	0	0	100
Water	1	1	1	23	0
Water + pyrethrum	1	9	1	2	73
Total Bordeaux, etc.	5	4	3	90	1
Total Bordeaux, etc. + pyrethrum	5	61	3	13	78

The tables show again that the Bordeaux and pyrethrum is a fairly efficient insecticide. The kill obtained, as would be expected, is lower with *Antestia* than with *Lygus*. The tables also show that there is apparently no action between the pyrethrum and any of the constituents of the Bordeaux. It appears that the liquid, whether it be Bordeaux or water, acts simply as a carrier of the pyrethrum particles on to the insect. A very finely ground powder should be used for this purpose, one capable of remaining in suspension in water for some time; it should mix thoroughly with the light blue Bordeaux to form a light green mixture. Although the figures given are very small for evidence on this point, it does appear probable that the pyrethrum with the spreader alone in water is the best mixture.

The conclusion is that pyrethrum powder may be mixed with Bordeaux, and the mixture, if sprayed thoroughly, forms an effective insecticide. Whether its

fungicidal action was at all impaired was not investigated. As however the pyrethrum powder is apparently unchanged, there is no reason to suspect that the constitution of the Bordeaux is changed either. Observations on a number of acres of coffee sprayed commercially with carbide-Bordeaux plus pyrethrum showed no decrease in its fungicidal action due to the addition.

The cost of the measure should be somewhat carefully examined. It appears that 1 lb. to 40 gallons is the lowest proportion of pyrethrum powder to Bordeaux that it would be economical to use, because the kill even at this strength is not complete. The cost of the measure can then be ascertained if we know the volume of Bordeaux used to a tree. The usual amount of Bordeaux mixture applied as a fungicide is $\frac{1}{2}$ to 1 gallon a tree. If the former volume only is applied, the use of pyrethrum mixture in it is of little value, because the volume, as has been shown, is quite inadequate for insecticidal purposes. At 1 gallon a tree, however, although this volume of spray cannot be considered completely adequate, the figures show that a high proportion of bugs is killed. At this rate of application, 1 gallon a tree and 1 lb. of powder to 40 gallons Bordeaux, 17 lb. of pyrethrum powder are required for an acre of 680 trees. The cost of the powder is therefore 25.50 sh. If the fungicide were definitely necessary and would be applied whether insects were present or not, this 25/50 might be counted as the entire cost of the insecticidal treatment, because all the expenses of application should then be costed to the fungicidal treatment. If, however, the spray were applied because it can act both as a fungicide and insecticide where it would not be applied against the insects or the fungus alone, then half the cost of the application must be accounted to each purpose. In comparing the cost of two insecticidal methods against the same insect, it is essential to detail the various costs in this manner.

It is clear in the above case that the cost of the material alone is greater than the cost of the pyrethrum-paraffin method; it is also less efficient, and therefore cannot be recommended for general use on coffee. There is, however, one other fact to be considered, that time is saved by doing the two operations in one, and the provision of extra labour for the two different sprayings is rendered unnecessary.

Bordeaux mixture with pyrethrum powder added does appear to be a valuable example of a combination fungicide and insecticide, and it seems highly probable that it may be of use on other crops where Bordeaux spraying is done and there are insects to be killed.

16. Economics of Spraying against *Lygus*.

The case of *Lygus simonyi*, unlike that of so many pests, is one in which a fairly closely accurate estimate of the financial loss it causes can be made. With *Antestia* there is no means of knowing the cash loss occasioned by the damage it does to the trees, which damage may continue to have its effect over a long period of time, and may adversely influence the tree in a number of ways. But *Lygus* causes a typical and usually unmistakable form of abortion of the flower-spike, and this appears to be the only damage it ordinarily does. To calculate the monetary loss it causes, it is therefore only necessary to know the tonnage which could be borne by the coffee, the proportion not realised owing to abortion of the flower-spike, and the value of the coffee. These variables may be estimated within fairly wide limits, and a sufficiently accurate idea of the loss can be obtained.

Thus, the writer has seen cases where the trees were in a good condition to bear heavy crops, and *Lygus* was present in numbers of over 100 to a tree, the loss having been at least 8 cwt. an acre, a reduction from a potential crop of $\frac{1}{2}$ ton an acre to about 2 cwt. This represents a cash loss of 480 shillings an acre. In many other cases the loss is considerably smaller; it may be a 50% or a 30% or only a 10%

loss on a potential crop of 10, 5, or 3 cwt. an acre. The value may be similarly calculated. A 10% loss on a potential 3 cwt. an acre would thus be a loss of 18 shillings an acre.

It is possible therefore to calculate the minimum loss it is economical to prevent by spending money on spraying, or in other words the extra crop required to pay for spraying, and above which profit is made. The calculation must be made on the value of the ripe crop on the trees, because all the costs of producing the crop on the trees are incurred whether the flower-spike is destroyed by insects or not, but on the other hand the costs of picking and factory work on the coffee are extra for the extra crop obtained. The following are actual figures, and they may for this purpose be taken as typical:—

	Per ton
Value of coffee when prepared ready to leave the plantation	1,355 shillings
Picking charges at 20 cents a <i>debe</i>	110 shillings
Plantation factory expenses	45 shillings
<hr/>	
Value of ripe coffee on the trees representing 1 ton of clean coffee	1,200 shillings

One spraying costing 15s. an acre is therefore paid for by one quarter (28 lb.) of coffee an acre. Supposing it necessary to spray three times, then any crop in excess of three quarters an acre saved by spraying represents profit. If then it is necessary to spray three times to realise a crop of 5 cwt., where 4 cwt. would have been realised if *Lygus* had not been controlled, the spraying shows a clear profit of 15s. an acre. And if 3 cwt. extra is obtained the profit is 135s. an acre.

In the experimental spraying described in Section 5, the increase of half-grown to three-quarter grown "cherries" represented 9 cwt. an acre of ripe coffee. In March the majority of this was nearly full-grown, and it is unlikely that the loss before ripening would be more than 10%. Accounting for such a loss we may reckon an increase of 8 cwt. an acre. After paying for the six sprayings there remains a profit of 390 sh. an acre.

It is of interest to ascertain the actual number of fruits to a tree necessary to produce one quarter an acre, and so to pay for one spraying. Average data for this calculation may be taken to be:—680 trees to the acre; 550 *madebe* to a ton of "clean" coffee; 8,000 berries to a *debe*. The number of berries on a tree to produce one quarter is therefore

$$\frac{550 \times 8,000}{680 \times 80} = 81 \text{ berries.}$$

Reckoning 40 primary branches on a coffee tree, this means that an average of two flower-spikes saved on a primary pays for one spraying.

17. Determination of Times at which to apply the Spray against *Lygus*.

The correct time at which to spray against *Lygus* depends on several factors, which vary independently, and so no general recommendation is possible. The chief of these factors are, the number of insects present, the time at which the first flowering occurs (which means in practice the time at which it can be expected to occur), the period over which flowerings occur, and the value of the flowering, that is, the amount of crop that can be expected from it.

The number of insects present can be ascertained with sufficient accuracy by test sprayings of numbers of trees selected at random. The number usually varies directly with the amount of fairly advanced flower-spike present, and nearly always increases after the first flowering of a season.

The times of first flowerings, and the period over which the trees will flower can only be estimated within wide limits, and this requires a detailed knowledge of conditions in the district. It can usually be done with fair accuracy, however, except in years when the rainfall varies more than usual from the average, both in amount and more especially in the season of precipitation, and so disturbs the usual flowering sequence, as happened in the latter part of 1929 and 1930.

The value of the flowering or flowerings expected has an importance in deciding the number of sprayings that it would be economical to apply should several prove to be necessary.

It will be seen, therefore, that each particular case has to be judged according to its own conditions in order to determine the necessity and times for spraying. It appears that protection of the flower buds may be obtained in some cases by two sprayings, and in other cases by not more than three. Thus if the main flowering is expected at the middle of March, it may be sufficient to spray once at the end of January and again between the middle and end of February. This will ensure almost complete protection from the time of first spraying until the middle of March. If the flowering occurs at this time, but it appears that there is still a further valuable flowering to come, it will be necessary to spray again. There are cases too in which the spike has been on the tree in an advanced stage for some time, when even as early as six weeks before the flowering arrives, the buds may already have been severely damaged.

From an examination of the anthers of the flowers it is possible at any time to discover how far the damage has gone. The anthers are dissected from the buds and examined with a hand-lens; if they are heavily spotted the flowers will not set fruit. It should be a routine practice on all plantations to ascertain the numbers of insects present by test sprayings, and to examine the flower buds for the typical damage by *Lygus* on the stamens.

A method of timing the sprayings against *Lygus*, which may prove the most generally useful, was suggested by the writer and carried out successfully on one plantation (Estate 7 of Section 18 in this paper). Here the trees were in a good condition to bear a heavy crop, and during the whole period from September till March, covering the two main flowerings, the average number of *Lygus* to a tree was ascertained every week in each block, by spraying ten trees selected at random in each block. Any block on which the number of *Lygus* was as high as 3 or 4 was sprayed. This method does not entail so many sprayings as might be expected, because no block is sprayed unless the numbers warrant it; and if perchance a spraying in one block may have been particularly effective, so that three weeks afterwards when the rule would have been to spray again, the insects are still under 3 or 4 to a tree, then the spraying is left until the numbers again appear, from the tests, to be at this level. As mentioned in Section 10, the value of being able to obtain an accurate knowledge of the *Lygus* infestation, for determining the times at which to spray, is evident here.*

This method will be of particular value where the trees are in good condition to bear a heavy crop, and seem likely to flower over a considerable interval of time.

18. Commercial Applications of Paraffin Extracts of Pyrethrum.

As stated previously a large number of planters have already applied this spray on a commercial scale, and it is possible to give details and results from actual practice. The chief details are classified in the following table.

*This method has been described by the writer, in detail, in Bull. Dept. Agric. Kenya 22 of 1932.

TABLE XVIII.
Details of Commercial Spraying.

Estate	No. of acres sprayed	No. of boy-days for spraying	No. of gallons of spray used	Cost of labour in shgs.	Cost of spray in shgs.	Total cost of application per acre in shgs.	Spraying for <i>Anesthia</i> or <i>Lygus</i> or both	Kind of spray used	Approximate average number of bugs per tree before spraying		Average number of bugs per tree after spraying
									<i>Lygus</i>	<i>Anesthia</i>	
1	58	279	150	149	576	15.80	<i>Lygus</i>	Local pyrethrum powder 1 lb. to 1 gall. paraffin	23		2.8
	58	208	148	110	554	14.50	<i>Lygus</i>	Do.	6		
2	59	350	148	187	568	16.20	<i>Lygus</i>	Do.	26		2.8
	59	260	148	139	555	14.90	<i>Lygus</i>	Do.			
3	35	330	104	135	387	14.90	<i>Lygus</i>	Do.	9		3
4	120	405	260	253	1,230	12.40	Both	Imported pyrethrum powder 1½ lb. to 1 gall. paraffin			
5	29	139		70			<i>Lygus</i>	Do.	50		
6	115	588	358	342	1,020	11.80	<i>Lygus</i>	Imported pyrethrum powder 1 lb. to 1 gall. paraffin	30		
7	158	648	589	308	1,864	13.70	<i>Anesthia</i>	Imported pyrethrum flowers 1 lb. to 1 gall. paraffin		60	
8	690	2,960	2,200	1,480	8,800	14.90	<i>Lygus</i>	Imported pyrethrum powder 1 lb. and 2 lb. to 1 gall. paraffin	9		1
9	46	252	141	120	465	12.70	Both	Imported pyrethrum powder 1 lb. to 1 gall. paraffin			
10	80	220	200	96	1,000	13.70	<i>Lygus</i>	Proprietary pyrethrum-paraffin spray No. 1	35		
11	11	27	32	19	160	16.30	Both	Do.	1	1	
12	8	84	32	35	160	24.40	Both	Do.	5	20	
13	70	480	100	216	900	15.90	<i>Lygus</i>	Do.			No. 2

As it was not possible to obtain exactly comparable information in each case, gaps in the table indicate that there is no recorded information on the point. Corrections in the cost per acre have been made in certain cases where the coffee was planted 9 ft. \times 9 ft. (537 trees an acre) to make it comparable with the cost of coffee planted 8 ft. \times 8 ft. (680 trees an acre), a more usual spacing which has been taken as a basis for calculations in this paper. The acreage figures can only be considered approximate, and other corrections ought probably to be made for complete accuracy. But with such large differences between the costs per acre of different applications, such corrections would not materially alter the average cost and have not been made.

In the application of such an insecticide there must be marked differences in the costs per acre such as are shown in the table, owing to the use of different sprays, differences in the size of the coffee trees and the thickness of their foliage, and many other differences. The fact that some trees may be so large as to require 5 gallons against 2½ gallons an acre necessary for smaller trees, making the cost of spraying nearly double in the first case, is of course compensated for by the fact that, other things being equal, the larger trees are capable of bearing more coffee.

The following averages are obtained from the table :—

To spray 1 acre requires	{	4.6 " boy-days " (that is one boy sprays on average
		148 trees in a day).
		3.0 gallons of spray.
		2/30 shillings expenditure on labour.
		11 30 shillings expenditure on materials, using
		pyrethrum powder and mixing it with paraffin
		on the farm.
		13/10 shillings expenditure on materials, using pro-
		prietary sprays.

The most effective spray used commercially was that made from local pyrethrum powder. Although the local powder was sold at a somewhat higher rate than the imported powders, its pyrethrin content was higher, and with one exception, an effective spray could be prepared from it at less cost than with imported powder.

The figure of 15 sh. an acre used in Section 16 was taken from the figures supplied in detail and with considerable accuracy from Estates 1 and 2. The figures were corrected from 537 trees an acre to 680 for the sake of uniformity. The spraying was carefully carried out, using a spray of high toxicity prepared from local powder. There was a considerable saving of labour on the second applications which cost 14 sh. 70 cents an acre. In order to have a margin to cover slight differences in conditions, 15 sh. was taken as the average figure for satisfactory applications of this method.

The following further details of some of the commercial sprayings are of importance.

Estate 6.—This was an application against *Antestia* on 158 acres, using american covers and spraying afterwards on the ground. A few *Lygus* were also obtained. The *Antestia* were present in numbers from 20 to 100 to a tree before spraying, and it was reported that it was difficult to find any *Antestia* one week after spraying. A second application was not made on this estate until some months afterwards. More than 107,000 trees were sprayed, which took 684 boy-days, that is, 157 trees were sprayed by a boy in a day, including the whole labour force employed; for example, it includes those boys mixing and carrying spray, and the head-men, and not only the boys actually spraying. The volume applied to an acre was 3.7 gallons; and the total cost of application (excluding the cost of covers and spray pumps, which were considered a capital charge) was 13 sh. 70 cents an acre.

Estate 7.—This was a series of applications against *Lygus* on a total of 690 acres of coffee. A few *Antestia* were also killed. Americani covers were used, except in the spraying of a few acres at the beginning of the work. More than 469,000 trees were sprayed, which took 2,960 boy-days, that is 158 trees were sprayed by a boy in a day. The volume applied to an acre was 3.2 gallons; and the total cost of application was 14 sh. 90 cents an acre. The trees on this estate in August 1930 were in a particularly fine condition, indicative of a heavy crop, there was promise of a good blossoming in the short rains (September to November 1931) and again before the long rains (February to March 1932). *Lygus* was present in August in fairly small numbers, but owing to the condition of the trees carrying a great amount of flower-spike there was likelihood of a very serious increase in their numbers. Spraying was therefore advised, and was carried out systematically. The average number of *Lygus* on each block was ascertained every week by spraying ten trees, and any block with an average of 4 or more to a tree was sprayed. By this means a very fine flowering was obtained in September and October and again in February and March, and the loss of crop was very slight. The following observations of the planter in charge of these sprayings are of interest:—

“In some areas where the trees were not in a very good bearing condition spraying was discontinued after the early blossoming. The increase of Capsid in these areas has been severe and practically all the later blossom has failed.

“The fact that we had suddenly to use 2 lb. of pyrethrum to 1 gallon of paraffin was a serious matter and immediately halved the available stock for later sprayings. As a result of this, certain areas have had to be left for a long period without spraying, and in consequence the Capsid has increased up to and over 50 per tree with consequent loss of crop. Where spraying has been carried out systematically the bug has been controlled and a good blossoming has already set.”

The conclusion that may be drawn from the foregoing details of commercial sprayings is encouraging. The method has been designed for less than a year, and already before experiments with it were completed, planters were applying it successfully in practice, and it immediately became the standard control for this insect. This indicates that when further experience with its application has been gained, it is likely to become a rapid, effective, and comparatively inexpensive means of reducing loss in all cases where *Lygus* is present; and that it will be a certain means of reducing infestations of *Antestia* when other methods fail.

Summary.

The application of an undiluted paraffin extract of pyrethrum for controlling *Antestia* and *Lygus simonyi* on coffee trees is described.

- (1) The spray is applied with a small hand “atomiser,” using 20 cc. of extract to a tree, and spraying under a cloth cover.
- (2) Tables are given with detailed figures in which the different methods of application may be compared. The kill of *Antestia* brought down by the most favourable method is 99%.
- (3) The proportion of insects brought down by the spray is in the neighbourhood of 96%. It appears that in practice a kill not much below 95% should be possible.
- (4) Of the *Lygus* on trees sprayed, 99% were brought down and the kill of these was complete.
- (5) The method is a dual control for *Antestia* and *Lygus*, and examples are given of trees sprayed when both these insects were present in serious numbers.

- (6) An experimental field spraying against *Lygus* is described in detail. It was shown that the numbers of *Lygus* could be kept below two to a tree by this spraying, and the proportion of fruit set on the sprayed block to that on the control was 3 : 2, indicating an increase of about 8 cwt. an acre.
- (7) The technique of the experimental sprayings, by which the detailed figures in the tables were obtained, is described. It is believed that these methods will be of more extended value in the experimental testing of sprays in the field.
- (8) The types of pump for the application of this spray are discussed. At present none is completely satisfactory.
- (9) An examination was made of the tendency to scorch coffee foliage of a number of proprietary kerosenes available for the extraction of this spray. It appears that the scorching varies directly with the unsaturated hydrocarbon content of the oil.
- (10) A biological method for comparing the toxicities of paraffin extracts of pyrethrum in the laboratory is described. This depends on data of the time taken to paralyse *Anesthia*, and not on mortality data, which proved unsatisfactory owing to the high ultimate mortality produced by comparatively weak extracts. A formula, based on the pyrethrin content of the powder, is suggested for the preparation of a spray against *Anesthia*.
- (11) The methods of preparing the extract on the plantation for use on a commercial scale are described. $\times \times, 500$
- (12) The value of this spray for determining the numbers of insects present is pointed out.
- (13) There is possible danger, in some cases, of causing an increase in the severity of attack by mealybug (*Pseudococcus lilacinus*) owing to the killing of its Coccinellid and other predators by the spray; but this has not yet happened in practice.
- (14) The spray has already been widely used as a commercial measure on coffee in Kenya, owing to the ease of application, and its much lower cost than other contact insecticides. It is suggested that there is a much wider field of utility for this spray on a large scale.
- (15) A comparison of the extract with a spray diluted in water was made. The extract at the rate of 4 gallons an acre proved superior to a water spray at the rate of 1,360 gallons an acre. The costs of application were respectively 12s. and 100s. an acre.
- (16) One pound of pyrethrum powder in 40 gallons of Bordeaux mixture proved to constitute a not unsatisfactory combined insecticide and fungicide. This mixture cannot be generally recommended for the control of insects on coffee, owing to its expense being greater than that of the extract spray, but it may be of value on other crops.
- (17) The economics of spraying against *Lygus* are discussed. It is shown that 1 quarter of coffee extra is needed to pay for one spraying. This represents no more than 81 berries to a tree.
- (18) Observations on the determination of the times at which to spray against *Lygus* are made, and a method of doing this which may prove generally satisfactory is suggested.
- (19) A number of details of various commercial applications of the spray are given. The cost per acre is in the neighbourhood of 14s. It has already come to be a standard control for *Lygus* in Kenya.

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THE LARVAE OF SOME WOOD-BORING ANOBIIDAE (COLEOPTERA).

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INTRODUCTORY.

During the biological studies now in progress at this laboratory upon the beetles of the family ANOBIIDAE definite identification of the larvae is necessary, and this investigation was therefore carried out in order to check and, if possible, expand the existing knowledge upon which the tables for separation of the various species are based. The best method for identifying immature stages of such insects is undoubtedly to keep a number until development is completed and then determine the species to which the adult beetle belongs. This method is, however, impracticable with the ANOBIIDAE since the larvae are extremely slow in their development and may take several years to complete their metamorphosis. Furthermore, it is extremely difficult, if not impossible, to get larvae which have been cut out of a piece of wood to enter it again and carry on their development; attempts to breed in sawdust have shown that this method is almost valueless, since the few larvae which succeed in completing their metamorphosis form very much undersized adults, presumably as the result of being unable to feed properly in the sawdust.

Finally, more than one species of Anobiid may occur in the same piece of wood and the determination by breeding of the identity of the larvae present is thereby greatly complicated.

The only alternative methods of identification are by characteristics of the habits or structure of the larvae. Knowledge of the type of damage caused, especially of the size and form of the frass and of the particular species of wood attacked is frequently of great help in distinguishing certain species present, but this method cannot always be relied upon, particularly if the infection is mixed. We must therefore fall back upon an examination of the structure of the larvae as giving the most convenient and accurate method of specific determination. Moreover, for ease of preparation and examination only the external morphology of these insects should need to be investigated.

Of the family ANOBIIDAE, eight species have been selected for inclusion in this paper. Seven of these species are wood-borers, the majority being common in occurrence, whilst the eighth species, *Sitodrepa panicea*, L., although not a wood-borer, has been included because material was available and this insect had previously been included in papers on the wood-boring species. The species chosen for study are as follows :—

Xestobium rufovillosum, De G.
Anobium punctatum, De G.
Ernobius mollis, L.
Ptilinus pectinicornis, L.
Priobium castaneum, F.
Ochina plinoides, Marsh.
Hedobia imperialis, L.
Sitodrepa panicea, L.

According to Pic¹⁷ in Junk & Schenkling's "Coleopterorum Catalogus" these genera fall into the following subfamilies :—

- | | | |
|------------------|-----|--|
| I. HEDOBIIINAE | ... | <i>Hedobia imperialis</i> , L. |
| II. DRYOPHILINAE | ... | <i>Priobium castaneum</i> , F. |
| III. ERNOBIINAE | ... | <i>Xestobium rufovillosum</i> , De G.
<i>Ernobius mollis</i> , L.
<i>Ochina plinoides</i> , Marsh. |
| IV. ANOBIINAE | ... | <i>Anobium punctatum</i> , De G.
<i>Sitodrepa panicea</i> , L. |
| V. PTILININAE | ... | <i>Ptilinus pectinicornis</i> , L. |

Classifying these genera on the structure of the larvae, however, Böving⁴ separates them into the following tribes :—

- | | | |
|-------------------|-----|---|
| I. HEDOBIIINI | ... | <i>Hedobia</i> |
| II. XESTOBIIINI | ... | <i>Xestobium</i> |
| III. ANOBIINI ... | ... | <i>Anobium</i> , <i>Sitodrepa</i> , <i>Priobium</i> |
| IV. XYLETINI | ... | <i>Ernobius</i> |
| V. PTILININI | ... | <i>Ptilinus</i> |

Böving does not include *Ochina* in his classification, but according to the characters by which he determines the tribes, this genus obviously should be placed in the ANOBIINI. As will be seen the two lists differ rather widely except for the genera *Hedobia* and *Ptilinus*. From the present study of the larvae it has been found impossible to arrive at any definite conclusion as to the relationship between the various genera, except that *Ptilinus pectinicornis* is clearly marked off by many structural features from the remainder. The larvae are all very similar in general structure, and when the smaller points of difference are considered it becomes obvious that the genera can be grouped in many different ways according to which characters are selected as the basis of classification.

The synonymy of the various species concerned is of little importance and can be obtained in detail from Junk & Schenkling's Catalogue;¹⁷ the following is a very brief summary giving the more common alternatives.

<i>Xestobium rufovillosum</i> , De G.	= <i>X. (Anobium) tessellatum</i> , F.
<i>Anobium punctatum</i> , De G.	= <i>A. domesticum</i> , Geoffr. <i>striatum</i> , Ol. <i>pertinax</i> , F.
<i>Ernobius mollis</i> , L.	= <i>Anobium molle</i> , L.
<i>Priobium excavatum</i> , Kugel.	= <i>P. castaneum</i> , F. <i>castaneum</i> , Reitt.
<i>Ochina ptinoides</i> , Marsh.	= <i>O. hederæ</i> , Müll.
<i>Hedobia imperialis</i> , L.	= <i>Ptinus imperialis</i> , L.
<i>Sitodrepa panicea</i> , L.	= <i>Anobium paniceum</i> , L.

Some doubt exists according to Pic in the synonymy of *Priobium*, as he puts a query-mark against the species *P. castaneum*, F. The adults associated with the larvae which I examined were determined, according to Fowler's "Coleoptera of the British Isles" Vol. IV, as *Priobium castaneum*, F., which is stated by this author to be synonymous with the species *P. tomentosum*, Muls. I think it best to use Fowler's nomenclature of *P. castaneum*, F., as the beetles agree with his description of this species.

LITERATURE AND PREVIOUS WORK.

A considerable quantity of literature exists in which mention is made of Anobiid larvae, but in very few papers is there any attempt to give a detailed description of the larvae. The earliest reference studied was that of Bjerkander,² but the first attempt at a detailed description seems to be that of Bouché,³ who in 1834 described the larvae of *Anobium tessellatum* and *Ptinus imperialis*. General descriptions of the Anobiid type of larvae are given by Ratzeburg¹⁹ and Westwood.²⁸ Perris¹⁵ described *Anobium molle*, F., at length and later¹⁶ gave an account of the structure of *Ptilinus pectinicornis* and a key for separating five of the species included in this paper. The only other earlier descriptions of Anobiid larvae that need be mentioned here are those of Taschenberg²⁶ on *Xestobium*, and Buddeberg⁵ on *Hedobia*.

Most of this earlier work, although fairly detailed, is not sufficiently accurate to be of much value in the construction of tables for determining the various species in question, since some of the statements are contradictory and a number of important characters upon which the later keys are based have been overlooked by the authors mentioned.

Of the more recent work upon this subject, Munro¹⁴ gives a detailed description with figures of the external morphology of *Anobium domesticum*, and his keys to the larvae of the furniture beetles include five of the species dealt with in this paper. Kemner¹³ considers four of these species and gives a key for their separation; this key has been repeated in a somewhat modified form by Van Emiden.⁶ Lastly, there is an important contribution by Böving,⁴ giving a key to twenty-six genera of the family ANOBIIDAE, which includes all the genera mentioned in this paper except *Ochina*.

Munro offers two keys, one based upon the distribution of spinules on the larvae, the method also used by Kemner, and the other based upon characters presented by the epistome and mouth-parts, this region being more favoured by Böving. The results of the present investigation show that some of the statements made by Munro and Kemner are doubtful, and Böving's key, is, at times, difficult to follow in the absence of drawings to illustrate the points raised; further, the majority of the characters emphasised by this last author require the preparation of permanent mounts for microscopic examination, thus precluding any possibility of identifying a single living larva without killing it.

MATERIAL.

Much of the material worked on in this investigation was collected and brought to the Forest Products Research Laboratory as part of the stock which is kept for breeding purposes. Other material was obtained from outside sources, as will be detailed later. In every instance, adults of the species in question were obtained from the material collected to supply larvae. In the case of *Ochina* and *Hedobia* two species of Anobiid larvae were obtained from each of the two lots of material, but in both cases the second species proved to be *Anobium punctatum*. The naming of the species was further checked by examination of the wood attacked and the type of damage caused, and finally by comparing, so far as possible, the characteristics of the larvae with those given in the keys previously mentioned.

As material came to hand, larvae were removed and, after fixing in Carnoy's fluid No. 2, were preserved in 70 per cent. alcohol. At the time of examination, however, live larvae were cut out of the wood, in order to make certain that observations on the preserved larvae were correct for living specimens. Any change which may have occurred during preservation, as, for example, modification of the folds of the body wall, was noted and corrected. In practice it was found that, on the whole, the effects of preservation could be ignored except when considering the natural curvature of the larvae and their general appearance as characterised by the swelling of the thoracic and posterior abdominal regions.

The largest individuals available were always chosen for examination, since it is intended that this paper should deal with the description and identification of fully grown larvae. Nevertheless, it is impossible to say with certainty that all the larvae examined were fully grown. There are considerable differences in structure between the first stage and completely developed larvae of the ANOBIIDAE, for work carried out at this Laboratory has shown that the newly emerged larva of the Death-Watch beetle (*Xestobium rufovillosum*) has no spinules and is able to move actively over the surface of the wood. Gahan⁹ has recorded similar observations on the first stage larva of the Common Furniture beetle (*Anobium punctatum*) and these have been confirmed during the course of investigations carried out at this laboratory. Janisch¹¹ also mentions that there are no spinules present on larvae of *Sitodrepa* in the first and second instars. As far as could be determined, however, from the results of the present work the differences in structure of the chitinous parts between half-grown and fully developed larvae were little, if any, more than the individual variations between apparently full-grown larvae.

The *Xestobium* larvae were obtained from old oak beams which form part of the laboratory's stock of material containing this insect. *Anobium* was found in walnut boards and willow basket-work, and *Ptilinus* larvae were cut out of beech and sycamore blocks. A supply of wood infested with the three species just mentioned is kept at the laboratory in order to obtain supplies of the insects for experimental purposes. *Ernobius* was found in large numbers beneath the bark of a plank of Sitka spruce in the laboratory's museum collection of timbers. *Priobium* larvae were discovered in an old walnut stump and *Ochina* in dead dry ivy stems on the wall of a house. *Hedobia* material was difficult to obtain. Some larvae sent to me by Miss E. Lyall, B.Sc., of the Department of Entomology, Royal College of Science, London, proved to belong to two species, *Anobium* and another unknown species. Since two adults of *Hedobia* were found in the birch stump from which all these larvae were removed, it was assumed that the unidentified larvae were *Hedobia*. This assumption was later confirmed by comparison with a larva of *Hedobia* kindly supplied to me by Mr. K. G. Blair, B.Sc., of the British Museum (Natural History). A culture of *Sitodrepa* was received from Mr. C. Potter, B.Sc., of the Stored Products Investigation, Biological Field Station, Slough; numerous larvae were present, in all stages of development, in almond kernels.

TECHNIQUE.

It has already been pointed out that both preserved and living material were used during the course of the investigation. Examinations of these whole larvae were carried out with a binocular microscope, as the stereoscopic effect was found to be most necessary for a correct appreciation of the larger characters of the insects.

After examination *in toto*, the heads were carefully cut off and the heads and bodies boiled vigorously for a few minutes in 10 per cent. caustic potash. Following washing in water, dehydrating in 50 per cent., 70 per cent., 95 per cent., and absolute alcohols, and clearing in clove oil, the skins were mounted in Canada balsam. The heads were dissected in the clove oil and separate mounts made of the dorsal portion of the head-capsule including the clypeus and labrum, the underside of the head-capsule, the right mandibles, left mandibles, and finally the maxillae and labium. In some cases, separate slides were also made of the legs.

The outlines of all drawings were made with the aid of a camera lucida, the only ones to present any difficulty being the drawings of the whole or anterior portion of a larva (figs. 1, 7). For these, preserved larvae, from which the superficial fluid was dried off, were sketched in parts through one tube of a binocular microscope and the various parts were then traced together to give a figure of the complete object: the details were checked on living larvae.

The large number of drawings included in this paper have been prepared with the object of giving a general impression of the various structures under consideration as seen with the aid of a microscope, and the correct chaetotaxy has been shown as far as possible. In this connection it should be pointed out, however, that when examining thin transparent objects under the low power it is frequently impossible to distinguish which setae are dorsal and which are ventral, and, in the drawings of objects under the low power, setae on both upper and lower surfaces are sometimes included to give the same general impression as that observed through the microscope. The chaetotaxy is explained in greater detail in the text.

THE ANOBIID TYPE OF LARVAE.

Most of the larvae of the ANOBIIDAE are borers and are modified in form and structure in accordance with their habits. The general appearance and structure of the larvae in this family are, therefore, very similar. All the fully grown larvae are soft-skinned, fleshy, of the curved scarabaeoid eruciform type, six-legged, and 5 to 10 mm. long. The body, greatly arched dorsally and flattened ventrally, is swollen anteriorly in the thoracic region and posteriorly in the region of the eighth and ninth abdominal segments. The posterior portion of the abdomen is curved ventrally, so that the tenth abdominal segment is pointing anteriorly. The colouring varies from creamy white to yellowish or pinkish, the head-capsule being a light testaceous with the epistomal chitination and mandibles ferruginous to pitchy black; the head and body are covered with fine, erect, golden-coloured setae.

Three thoracic and ten abdominal segments are visible (fig. 1); most investigators seem to recognise only nine abdominal segments, and the tenth segment, if commented upon, is said to take the form of three small tubercles placed round the anal opening. I am, however, of the opinion that in the Anobiids examined the tenth segment is larger and more distinct than is implied by the term "tuberculate." The thoracic and first eight abdominal segments are subdivided by well marked grooves into cushion-like folds of the body-wall.

A number of segments have dorsal bands of small, dark-brown spinules which are sufficiently constant in disposition to form an important character for the determination of species. The spinules have their apices recurved, so that they point posteriorly, and it is now generally accepted that they aid the larva to get a purchase on the

walls of the tunnel when boring. According to Perris, these spinules are peculiar to the larvae of this family of beetles.

There is one pair of thoracic spiracles placed between the prothorax and mesothorax, and eight pairs of abdominal spiracles present on the first eight abdominal segments. The spiracles are small, have a narrow yellowish oval peritreme, and are usually difficult to see; the thoracic spiracles are always, and the first abdominal sometimes, larger than the remainder. The degree of development of a curious tubular prolongation of the peritreme has been used by Böving⁴ as an accessory character in his key.

The head-capsule shows only two sutures, an epicranial and a fronto-clypeal. No frontal sutures, as figured by Munro,¹⁴ are present, nor could I determine any sutures on the underside of the head-capsule. The epicranial suture is well-marked and extends from a small depression in the middle of the dorsal surface of the capsule posteriorly over the vertex to the occipital foramen. This suture seems to have been formed by an in-pushing of the chitin, so that inside the head-capsule and following the course of the suture there is a double septum which apparently serves for the attachment of the powerful mandibular muscles. The epistome, or anterior portion of the frontal area, is more heavily chitinised or pigmented than the remainder of the head-capsule; the extent of chitinisation and the epistomal chaetotaxy are of specific importance. The "hypopharyngeal bracon," a narrow strip of chitin running transversely across the maxillary foramen, and referred to by Munro, was not distinguished in any of the Anobiid larvae examined.

The antennae are minute, retractile, and one or two-segmented, occurring in pits at the lateral margins of the epistome. Kenner¹³ has figured the antennae of four species and indicates that they may form an evolutionary series.

Considerable difficulty was encountered in attempting to determine the presence or absence of ocelli. Perris¹⁵ saw eyes on all the species which he examined and notes that there is one on either side of the head near the inferior angle of the mandible. Although pigment spots with slight cornea formation are distinguishable in the position mentioned by Perris in some species, no trace of ocelli could be seen in others.

The clypeus is a separate sclerite but is very weakly chitinised. In all the species examined there is a group of two or more setae at each posterior angle of the clypeus, the bases of the setae being inserted at the junction of the clypeus and epistome. These groups are referred to as clypeal setae, since in *Hedobia* they obviously arise on the clypeus and not the epistome. It is presumed that in the other species their origin has been shifted posteriorly until they appear to spring from the clypeo-epistomal junction or even from the epistome.

The mouth-parts are well developed and are directed ventrally. The labrum is always present and distinct from the clypeus and has its posterior angles greatly thickened to form well marked tormae which may be fused with the so-called labral hooks, a pair of slender chitinous rods extending posteriorly from the labrum. Munro states that these hooks serve for the attachment of the muscles moving the labrum, but I am inclined to think that they are present as supports for the anterior portion of the epipharynx. The ventral surface of the labrum, which Böving refers to as the epipharynx, is usually beset with a number of strong spines and setae.

The mandibles are large and powerful, toothed but without a molar process, and having a large rounded condyle at their outer angle.

The fleshy maxillae have a distinct cardo and stipes, the latter being strengthened on its inner margin by a more strongly chitinised stipital rod. The mala is usually divided into an inner and an outer lobe and armed with strong spines and setae; the maxillary palp has three segments.

The labium is also fleshy and mostly membranous and closely united to the maxillae. The mentum is separated from the submentum by a narrow postmental

band of chitin. The ligula is small, conical or rounded, and setose; the labial palps are composed of two segments.

A typical thoracic segment, e.g., mesothorax, can be divided into seven folds of the body-wall. It is impossible to homologise these folds with divisions of the segmental sclerites of adult insects, and the finding of suitable names for these folds is therefore a difficult problem. A nomenclature which will give an idea of the relative positions of these folds is desirable, however, and of the many terms which have been used I am of the opinion that the following are the most suitable. When viewed dorsally the segment is divided into an anterior or "prenotal" fold and a posterior or "postnotal" fold. The postnotal fold is, perhaps, not too well named, since it extends sufficiently far laterally to embrace the spiracles, but I think the terms "prenotal" and "postnotal" are rather less restricted in application than "scutal" and "scutellar," the terms used by some writers. For the lateral fold, corresponding to that which in the abdominal segments lies immediately below the spiracle, I think the term "hypopleural" is satisfactory, and for the fold between the hypopleural and the leg the term "pedal" will answer, since pedal folds do not occur on the abdominal segments. The fold on the ventral surface between the pedal folds is the sternal fold. A complete segment consists, then, of the following folds—a prenotal, a postnotal, two hypopleurals, two pedals and a sternal.

The legs are generally five-segmented. It is very difficult to make out the number of segments, and some species seem to have only four, the doubtful segment being the trochanter. Even when the trochanter is distinct the insect does not appear to be able to bend its leg at the trochantero-femoral joint with the same facility as at any of the other articulations. A study of the musculature of the leg of *Xestobium*, however, showed that muscles are present for moving the coxa, trochanter, femur and tibia; although no muscles were seen to work the tarsus, this segment seems to be articulated with and distinct from the tibia. The legs are short, end in a strong tarsal claw, and are seemingly of little or no use for locomotion. Munro, Kemner and Judeich-Nitsche¹² all give five as the number of segments in the Anobiid larval leg, but Zacher²⁹ gives only four.

The thoracic spiracle lies in a deep depression between the prothoracic hypopleural and mesothoracic hypopleural folds.

The first eight abdominal segments are divided into folds resembling those of the thorax, but the pedal folds are wanting. The region of the eighth segment is usually somewhat swollen and the end of the abdomen is bent ventrally and forwards.

The abdominal spiracles occur at the ventral margins of the postnotal folds of the first eight segments.

The anus is a transverse slit on the tenth abdominal segment. Just below it is a longitudinal groove bounded laterally and ventrally by a chitinous band which is produced internally for some distance apparently as a strengthening for the rectal wall.

DESCRIPTIONS OF LARVAE.

In the following descriptions, *Xestobium* is taken as the type and is therefore treated in a little more detail than the remaining species.

***Xestobium rufovillosum*, De G.**

The larva of *Xestobium* (fig. 1) is the largest of the Anobiid larvae, measuring up to 11 mm. in length. The head is yellowish, circular in outline, set nearly vertically in the prothorax. The chitinated epistomal area is small, linear and dark brown in

colour; the mandibles are nearly black. The body is markedly swollen in the thoracic region, very slightly in the region of the eighth abdominal segment, and is covered with long, fine, golden setae which stand erect from the surface of the body. The last three abdominal segments are curved forwards ventrally under the body.

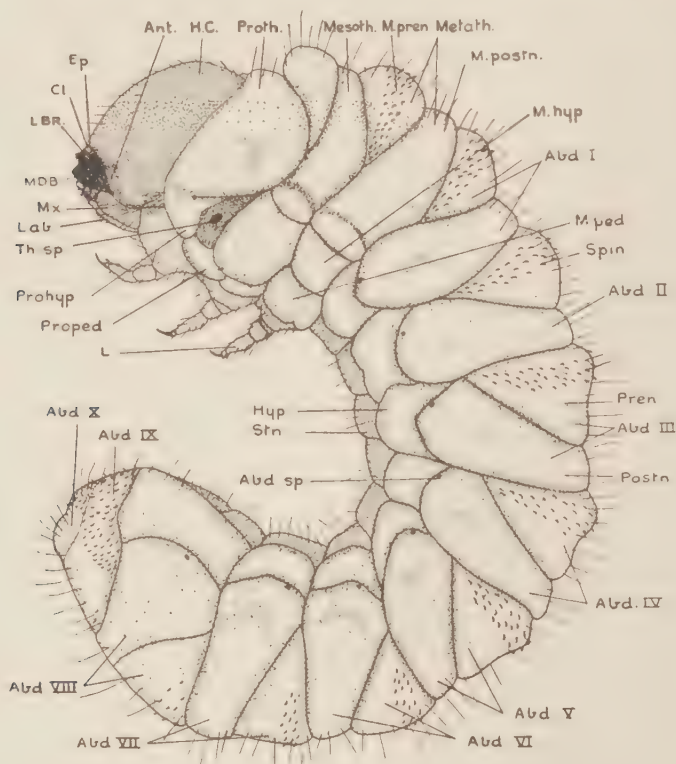


Fig. 1. *Xestobium rufovillosum*, De G.: larva, lateral view (x 15).
For explanation of lettering to figs. 1-15 see p. 68.

Head-capsule.

The head-capsule is somewhat flattened dorso-ventrally, and is covered with fine, short, erect, golden setae except for a transverse area just behind the epistome and that region which is normally enclosed by the prothorax. Dorsally can be seen the epicranial suture, which is a very clearly marked median longitudinal groove extending from the vertex to approximately halfway down the "face," where it terminates in a small depression. Ventrally (fig. 2a) no sutures are apparent except the continuation of the epicranial. The occipital foramen is large and oval. Anteriorly, on either side, is a well chitinised genal fossa which receives the mandibular condyle. The gular plate is narrow and transverse and bears on its anterior margin a pair of projecting lobes and a pair of strongly chitinised tubercles which serve for the articulation of the maxillary cardines; the gular lobes act, possibly, as points of attachment of the labial muscles. Setae are wanting on the ventral surface except for a few on the projections bearing the genal fossae.

The epistome (fig. 3a) is broad and very short, being about eight times as wide as long. It is deeply pigmented except for a small median area. Laterally, the anterior margin is strengthened to form prominent condyles and, set on a level with the lateral

margins of the clypeus, is a pair of smaller thickenings, which articulate with the inner angle of the mandible. A group of 8-9 setae occurs on each side of the middle line just within the anterior margin, and there is a distinct group of about seven at each posterior angle of the epistomal chitination.

The antennae (fig. 2d) are minute, retractile, poorly chitinated, two-segmented, and protected posteriorly by an extension of the epistomal chitination. The basal segment bears a small apical segment and an elongate, stalked, somewhat conical appendix, to which Kemner¹³ ascribes a tactile function. So far as could be distinguished, three setae are present on the basal piece, while the apical segment has four stout setae and a small basiconic process. On the membrane of the basal segment can be seen three large, oval, margined areas which have, perhaps, some sensory function.

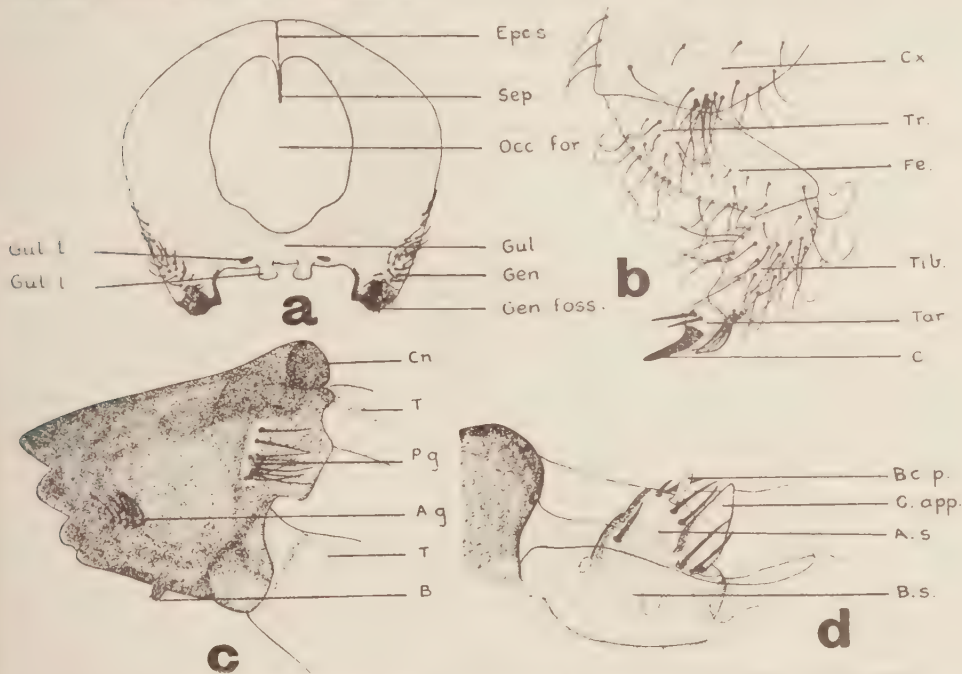


Fig. 2. *Xestobium rufovillosum*, De G.: a, underside of head-capsule (x 25); b, leg (x 90); c, mandible—dorsal view (x 90); d, antenna (x 410).

Although ocelli are present in the newly hatched larva, no signs of them could be discovered in the fully grown larvae. The clypeus (fig. 3a) is a thinly chitinated sclerite, rectangular in shape, nearly five times as wide as long, with the anterior angles right-angled and broadly rounded. Posteriorly, just in front of the epistomal margin, are two lateral groups of about twelve setae each.

Mouth-parts.

The labrum (fig. 3a, c) is transverse and approximately oval in outline, being rounded anteriorly and laterally but straight along its posterior margin; the posterior angles are greatly thickened and produced to form the tormae. Running backwards from just within the posterior edge of the labrum is a pair of elongate, slender rods, the labral hooks, which are not fused with the tormae as in some other species. Dorsally, the labrum bears on its anterior two-thirds a large number of setae, as shown in fig. 3a. The ventral surface of the labrum, which Böving refers to as the epipharynx, bears a number of stout spines and setae (fig. 3c). A group of five stout

setae occurs medially on the anterior margin, with a row of 8-10 extending laterally on each side; on either side of the middle line is a series of 9-12 strong, flattened, truncate spines set on an arc, as shown in fig. 3c.

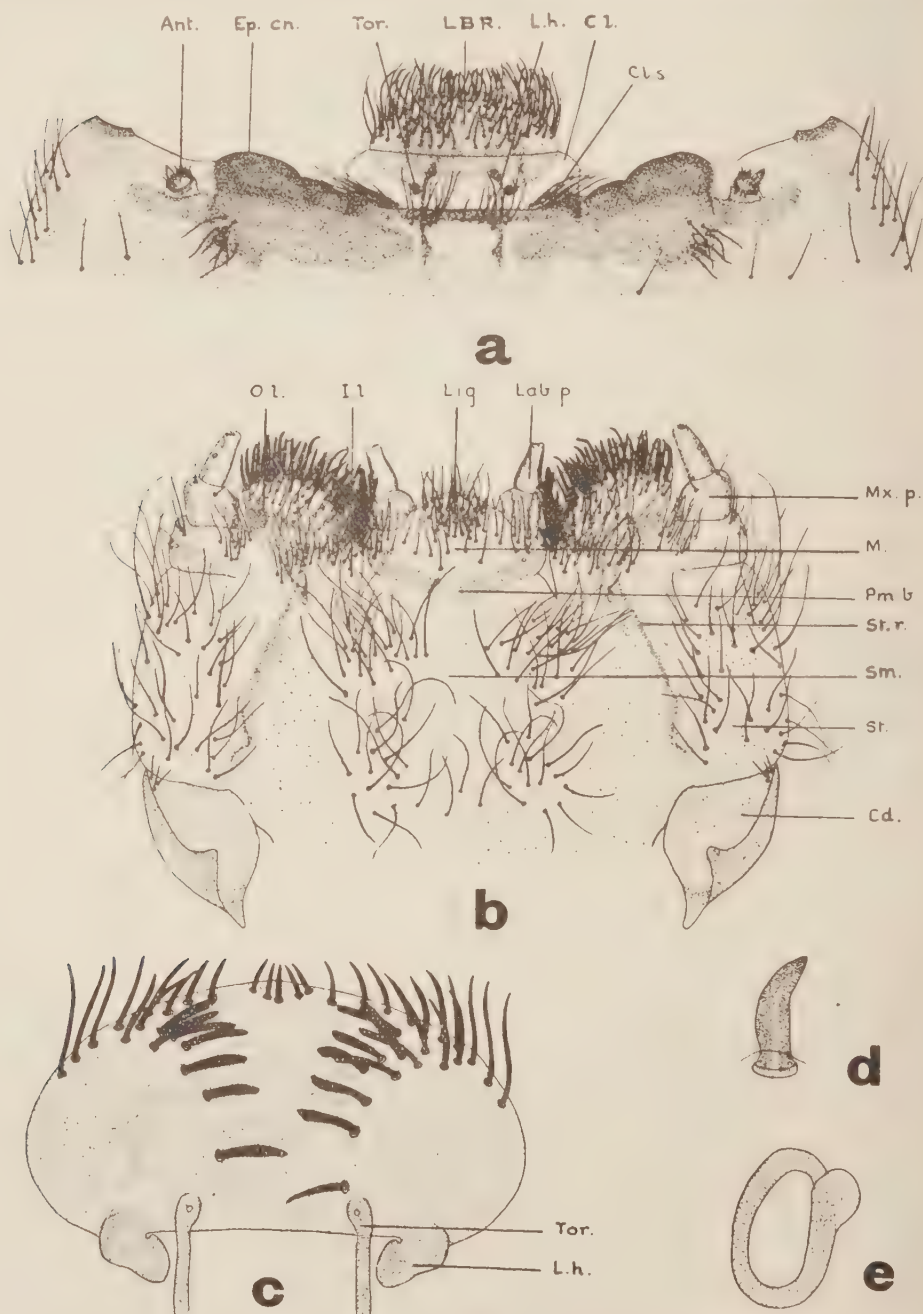


Fig. 3. *Xestobium rufovillosum*, De G.: a, epistome (x 90); b, maxillae and labium (x 90); c, labrum—ventral view (x 225); d, spinule (x 410); e, spiracle (x 410).

The mandibles (fig. 2c) are large, very strongly chitinised throughout, quadridentate and bear a prominent condyle. Dorsally, each mandible has two groups of setae, a row of about ten near the posterior margin and a group of the same number more anteriorly. Ventrally, there is a small "brush" of setae set in a slight depression on the inner edge of the mandible. The mandibular tendons are broad and strong and are prolonged backwards as far as the epicranial septum.

The maxillae (fig. 3b) are for the most part thinly chitinised and closely bound to the labium. The cardo is curved, rather cradle-like, emarginate posteriorly and bears three small setae at its external anterior angle; it is more strongly chitinised posteriorly. The stipes is large, rectangular, beset with numerous setae and has along its inner margin a chitinised rod-like thickening which terminates anteriorly in the inner lobe of the mala. About the level of the base of the palp, there can be seen in this stipital rod a pit with a small seta just in front of it; this pit and seta structure occurs in all the Anobiid larvae examined and its functional significance is unknown. Distally, the stipes bears a stout three-segmented palp and a large mala. The basal segment of the palp is poorly chitinised anteriorly and bears a number of setae, the intermediate segment only two setae and two sensory pits, while the apical segment lacks setae but has one pit and terminally a group of small sensory papillae. The mala is bilobed, the inner lobe being small and bearing one very large and strong spine, two or three more slender spines and a few setae. The outer lobe is large and bears on its distal margin a dense series of strong spine-like setae, some of which are flattened and truncate; this series of setae extends in the form of a broad band some distance on to the dorsal and ventral surfaces and then merges into the setae which cover most of the posterior part of this lobe.

The labium (fig. 3b) is for the most part membranous and but little chitinised. The submentum is very broad, and on its ventral surface can be seen on either side of the middle line an anterior group of 20-25 long setae and a posterior group of 12-18 setae. The mentum is small and demarcated from the submentum by a more strongly chitinised postmental band. A series of scattered setae extends transversely across the mentum. The anterior margin of the mentum is slightly produced and broadly rounded, forming an ill-defined ligula covered with a wide band of stout setae, which are more numerous dorsally than ventrally. The palps are two-segmented and devoid of setae, but each segment has one pit, and the apical segment has in addition a terminal group of minute sensory papillae, one of which is bulbous and much larger than any of the remainder.

Thorax.

Each of the three thoracic segments is divided by folds of the body-wall, as shown in fig. 1, and the thoracic region appears to be swollen in contrast with the rest of the body.

On the prothorax the notal fold is large and not subdivided into pre- and postnotal folds and fits closely round the posterior portion of the head-capsule. The hypopleural folds are small and incompletely separated from the notal fold. The pedal folds are also small and lie somewhat posterior to the hypopleural folds.

The mesothorax is divided dorsally into pre- and postnotal folds; the hypopleurals are large and the pedals small.

The metathorax resembles the mesothorax except that the hypopleurals are smaller and the pedal folds larger. In addition, on the metaprenotal fold, there is a band of small, brown, recurved spinules which are in rows about four deep near the middle dorsal line of the insect.

Large spiracles occur in deep lateral depressions between the prothorax and the mesothorax.

Each thoracic segment bears a pair of well-developed five-segmented legs. The coxa (fig. 2*b*) is short and broad and sparsely setose but has a small group at its external apical angle. The trochanter is triangular and bears a number of fine setae; it is imperfectly articulated with the femur. The femur is stout, twice as long as broad and setose on its inner side. The tibia is of about the same length as the femur though less stout; it is relatively thickly clothed with long, fine setae and bears at its apical external angle a group of about five much stronger setae set closely together. The tarsus is small, carrying apically a strong, slightly curved claw and internally, just below the base of the claw, two short spine-like setae.

Abdomen.

The abdomen (fig. 1) comprises ten segments, the first eight of which are divided into folds like the thoracic segments, but the pedal folds are lacking. The ninth and tenth abdominal segments are not divided into folds. Setae are especially numerous on the hypopleural folds.

Spinules occur on the prenotal folds of the first eight abdominal segments, and laterally and ventrally on the ninth and tenth segments. On segments 1-6 the spinules are in rows 4-5 deep at the mid-dorsal line; 2-3 rows occur on segment 7 and only a few scattered spinules appear on segment 8; segments 9 and 10 have numerous spinules. A typical spinule is shown in fig. 3*d* and can clearly be seen to be hollow and somewhat sunk in the skin basally.

The spiracles are somewhat variable in form but a typical outline is shown in fig. 3*c*. The curious funnel-like prolongation of the peritreme is not very large in this species. Owing to its transparency, the structure of the spiracle is difficult to make out, but there is a large atrium and a definite closing apparatus.

Notes.

Xestobium rufovillosum is a species of considerable economic importance attacking structural timbers in old and frequently historic buildings; oak is the timber most commonly infested, but elm, chestnut, alder and pine have also been recorded as attacked by this pest. Its natural habitat is in dead parts of the trunks and large branches of living trees, such as oak, chestnut, willow, hawthorn, etc. The frass, which consists of relatively large lenticular or bun-shaped pellets, is characteristic of this insect.

Ratzeburg¹⁹ gives a good description of the larva but says that the antennae are one-segmented and the legs three-segmented. Perris¹⁵ states that spinules are present on the metathorax and first seven abdominal segments. Taschenberg²⁶ records indications of eyes, and spinules on the anal segment. Munro¹⁴ in his key asserts that this larva has spinules on the metathorax, first six and the ninth abdominal segments only and in his figure shows a row of setae along the anterior margin of the epistome and no clypeal setae. Kemner¹³ uses as a character for the separation of *Xestobium* the absence of spinules from the eighth abdominal segment but records spinules on the ninth.

Anobium punctatum, De G.

The larva of *Anobium* is very similar in general appearance to that of *Xestobium* but is smaller, attaining a length of about 7 mm. The thoracic and abdominal swellings are rather more marked than in *Xestobium*. The larva is covered with fine, erect, golden setae and the posterior end of the abdomen is curved forwards ventrally.

Head-capsule.

Except for size, epistomal chitinisation and chaetotaxy, the head-capsule of this species very closely resembles that of *Xestobium*. The short setae which are present extend anteriorly up to the epistomal chitinisation without an interval.

The epistome (fig. 4a) is approximately five times as wide as long, deeply pigmented and clearly marked off posteriorly from the rest of the head-capsule. The condyles are not quite so distinctly marked as in *Xestobium*. On the anterior border of the epistome are two setae only, one on either side of the middle line, sometimes close together and sometimes halfway between the centre and the lateral margins of the clypeus. Apart from the pair of setae already mentioned and a long seta laterally by the antennal pit, there are no setae on the anterior half of the epistome; there are no groups of setae at the posterior angles. A few scattered setae occur on the posterior half of the epistomal chitinisation.

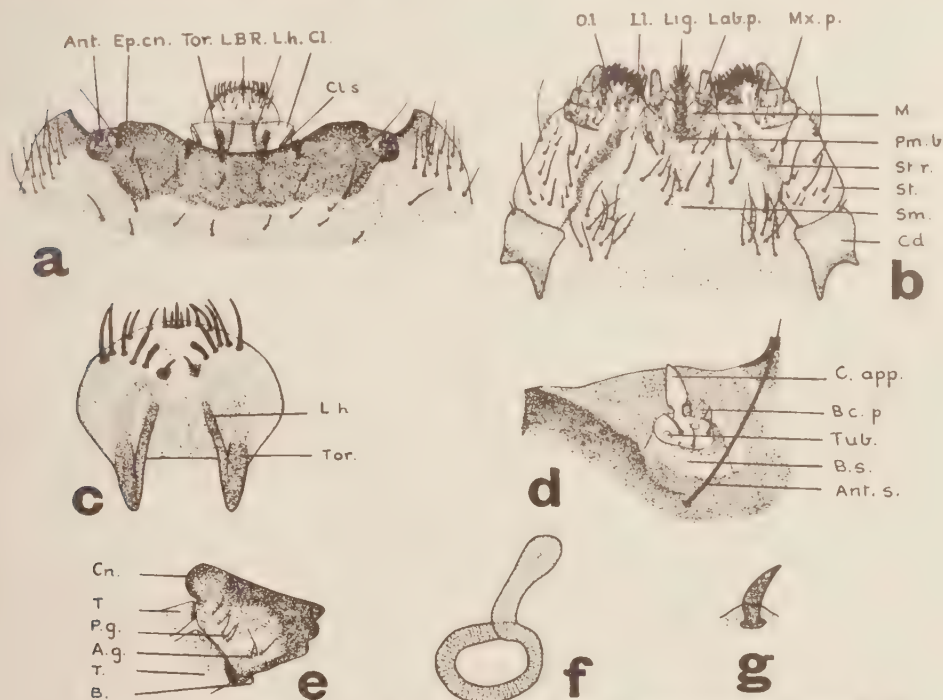


Fig. 4. *Anobium punctatum*, De G.: a, epistome (x 90); b, maxillae and labium (x 90); c, labrum—ventral view (x 225); d, antenna (x 410); e, mandible—dorsal view (x 90); f, spiracle (x 410); g, spinule (x 410).

The antennae (fig. 4d) are minute and situated in pits entirely surrounded by a ring of chitinisation. The basal segment bears a large, stalked, conical appendix, but no signs of the reduced apical segment figured by Kemner¹³ could be seen. The smaller basiconic appendage occurring in *Xestobium*, on the apical segment now appears on the basal segment; in addition, four setae can be distinguished and a small hemispherical protuberance. In the wall of the basal segment can be seen two oval, margined areas which are more transparent than the surrounding membrane.

On either side of the head, just behind the inferior angle of the mandible, is a minute lens-like projection and beneath the surface is a small spot of greyish pigment; these no doubt represent a somewhat degenerate ocellus.

The clypeus (fig. 4a) is similar to that of *Xestobium* but is four times as wide as long, has the anterior margin slightly sinuous, and has at both its posterior angles a group of only two setae.

Mouth-parts.

The labrum (fig. 4a, c) is much more circular in outline than that of *Xestobium* and has its posterior angles greatly thickened and produced to form backwardly projecting tormae, which are fused posteriorly with the labral hooks. Dorsally, the labrum bears on its anterior half about 15 fine scattered setae, and just in front of the margin of the clypeus is a transverse row of three pits. The ventral surface of the labrum, or epipharynx, bears a number of stout spines and setae as shown in fig. 4c. The small posterior pair of spines are mounted on slight thickenings of the epipharynx.

The mandibles (fig. 4e) are tridentate. Dorsally, there are two groups of setae, as in *Xestobium*, the posterior row consisting of 3-6, and the more anterior group of three setae. Ventrally there is a small brush of backwardly directed hairs.

The maxillae (fig. 4b) are closely bound together by the submental membrane of the labium. The cardo is emarginate and more strongly chitinised posteriorly and bears a single seta at its external apical angle. The stipes is rectangular, twice as long as broad, and bounded internally by a well-marked stipital rod showing a pit and seta near its upper end. The three segments of the palp are rather short and broad; the basal and intermediate segments bear a few setae. The mala is large and is divided into inner and outer lobes, the inner being slightly larger in relation to the outer than in *Xestobium*. The inner lobe has anteriorly a number of spines more or less equal in size and posteriorly a few setae, and the outer lobe is furnished along its anterior margin with rows of short, stout, truncate spines. A few strong setae extend along the lateral margin of the outer lobe.

The labium (fig. 4b) is membranous, as in *Xestobium*. The submentum is large and has two posterior groups of about ten setae each on its ventral surface; the anterior groups noticed in *Xestobium* are merged into one scattered group of 20-25 setae. The postmental band is well marked. The ligula is somewhat conical, rounded apically, and is furnished with a double row of strong setae extending posteriorly on to the mentum; the bases of these setae are set on a rather more deeply pigmented band. The mentum also has a few setae laterally below the palps, which are two-segmented and lacking in setae. There is no bulbous sensory papilla at the tip of the apical segment of the labial palp.

Thorax.

The prothorax is very similar to that of *Xestobium*.

The mesothoracic prenotal fold is divided into two halves by a transverse furrow.

The metathorax resembles that of *Xestobium*, and on the prenotal fold has a band of spinules which are in rows two or three deep near the mid-dorsal line.

A large spiracle occurs on each side of the body in a deep depression between the prothorax and mesothorax.

The legs are five-segmented, with fewer setae than those of *Xestobium*, a relatively longer claw and shorter and stouter femur and tibia. The group at the apical external angle of the tibia comprises three setae and two fine setae occur just below the claw on the tarsal segment.

Abdomen.

The prenotal folds are relatively larger in relation to the postnotal folds than in *Xestobium*.

Spinules occur on the prenotal folds of the first seven abdominal segments only and are wanting in the eighth, ninth, and tenth segments. The bands on the first six segments have two rows of spinules and that on the seventh only a single row. A typical spinule is shown in fig. 4g.

The spiracles of this species, as may be seen from fig. 4f, have a tubular projection which is quite as long as the spiracle and is more developed than in any other species considered in this paper.

Notes.

Anobium punctatum is a pest of considerable economic importance in furniture and structural timbers; dead branches of trees and shrubs are the natural habitat. Almost all timbers, whether hardwood or softwood, are liable to attack. The faecal pellets are small, short and fusiform or cylindrical.

Houlbert¹⁰ gives the legs as three-segmented and the mandibles quadridentate. Munro¹⁴ gives a full description and says that spinules are to be seen on the metathorax and first eight abdominal segments. Picard¹⁸ states that spinules are present on all the abdominal segments and the metathorax. Altson,¹ Kemmer¹³ and Galan⁹ record the presence of ocelli; the last author reports the presence of spinules on the metathorax and first six abdominal segments.

Ernobius mollis, L.

The larva of *Ernobius* in many ways resembles very closely indeed that of *Xestobium*. It is 8 mm. in length, curved, and the general body-colour is yellowish or pinkish; the setae covering the body are relatively shorter and the body less swollen in the thoracic region than in *Xestobium*.

Head-capsule.

The head-capsule of *Ernobius* can be distinguished immediately from that of *Xestobium* by the extent of the epistomal chitinisation (fig. 5a), which is semicircular in outline and includes most of the frontal area of the head. The condyles are moderately prominent. The anterior margin is entirely devoid of setae, as also is a rectangular area immediately behind it. Short, erect setae are generally distributed over the rest of the chitinated area and head-capsule, but there is a distinct group of 14-18 longer setae at a short distance behind the antennal pits corresponding in position with the groups at the posterior angles of the epistome of *Xestobium*.

The antennae (fig. 6c) are minute and two-segmented and set in pits which are protected posteriorly by a wing-like extension of the epistomal chitinisation. The basal segment carries two setae and a large, stalked, subconical appendix; two bordered oval areas appear in the wall of this segment. On the apical segment, which appears as a flattened protuberance on the basal segment, can be seen four setae, a basiconic appendix and a small hemispherical tubercle, which may be a sensory papilla or, perhaps, the remains of a degenerate third segment.

No signs of ocelli could be detected.

The clypeus (fig. 5a) is transverse, $2\frac{1}{2}$ times as wide as long, with the anterior angles obtuse and rounded; at each of the posterior angles is a group of about eleven setae.

Mouth-parts.

The labrum (figs. 5a, 6b) is intermediate in outline between those of *Xestobium* and *Anobium* and is noticeably emarginate anteriorly. The posterior angles are thickened and produced into backwardly projecting rod-like tormae. There is no union of the tormae and labral hooks, which are long and very slender. Dorsally,

the labrum bears two groups of setae on each side of the middle line (fig. 5a). The first group contains 35–40 setae arranged along the anterior margin and extending some distance laterally; the second group consists of 6–8 just posterior to the first group and nearer the middle line. On the ventral surface there are more spines, but of smaller size, than occur in either *Xestobium* or *Anobium*; their number and disposition, both of which are variable within small limits, are shown in fig. 6b.

The mandibles (fig. 6d) are usually quadridentate but sometimes show only three teeth. Dorsally, the posterior row consists of 12–14 short setae extending over the outer edge of the mandible on to the ventral side, and the anterior group contains about three setae placed on a level with the interval between the second and third teeth. Ventrally is a well developed brush of relatively long setae projecting beyond the inner edge of the mandible.

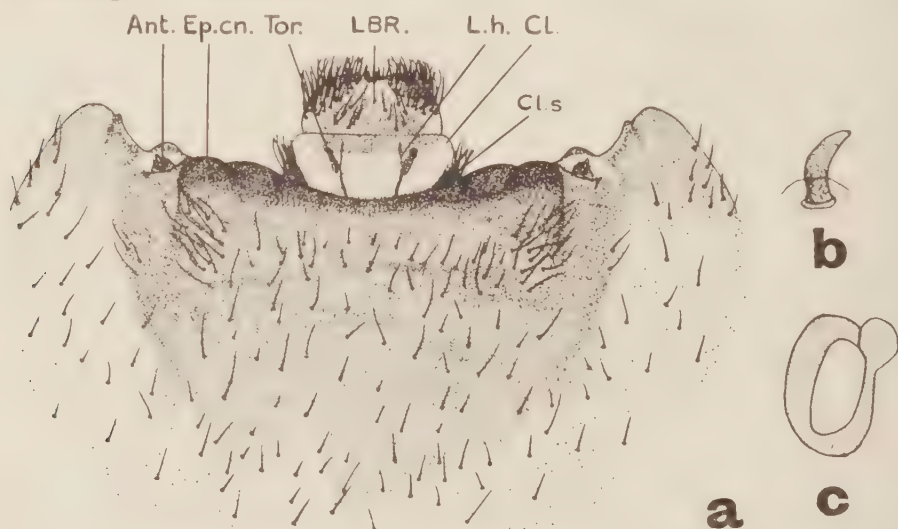


Fig. 5. *Ernobius mollis*, L.: a, epistome (x 90); b, spinule (x 410); c, spiracle (x 410).

The maxillae (fig. 6a) are rather more heavily chitinised than those of *Anobium* or *Xestobium*. The cardo is relatively large, equally chitinised all over, emarginate posteriorly and bears two setae at its external apical angle. The stipes is well chitinised except for an area round the base of the palp and is provided with a number of fairly long setae. The stipital rod is well developed anteriorly but disappears posteriorly in the general chitinisation; a seta and pit are present in a position just below the level of the base of the palp. The three-segmented palp is similar to that of *Xestobium*. The mala is divided into two lobes, the inner of which is half as large as the outer. The inner lobe bears about six long spines and numerous very fine setae, and the outer lobe bears short truncate, flattened spines and fine setae.

The labium is shown in fig. 6a. The submentum is broad and membranous and bears ventrally an anterior group of 12–16 and a posterior group of about 10 setae on either side of the middle line. The postmental band is broad and well marked and the mentum and the ligula are more chitinised than the submental membrane. The palps are relatively shorter and stouter and the ligula rather longer than in *Xestobium*, but the latter is not conical as in *Anobium*.

Thorax.

The structure of the thorax is of the normal Anobiid type as described for *Xestobium* but the pedal folds are relatively rather smaller.

On the prenotal fold of the metathorax is a band of spinules which are in rows three or four deep near the mid-dorsal line.

A large spiracle occurs in the lateral depression between the prothorax and mesothorax.

The legs are well developed, five-segmented, and moderately setose. The tibia is more elongate and the tarsus larger than in *Xestobium*. The claw is curved and strongly chitinated and below it on the tarsus are two setae; only two setae appear in the group at the external apical angle of the tibia.

Abdomen.

The segments of the abdomen resemble closely those of *Xestobium*. Spinules are found on the prenotal folds of the first eight abdominal segments, laterally and dorsally on the ninth, and latero-ventrally on the tenth. On the first six segments there are 3-5 spinules in a row near the mid-dorsal line and a few scattered spinules occur on the seventh and eighth segments; on the ninth the spinules are numerous laterally and scattered dorsally, and the tenth has a small group of setae on either side just below the level of the anal opening. A typical spinule is shown in fig. 5b.

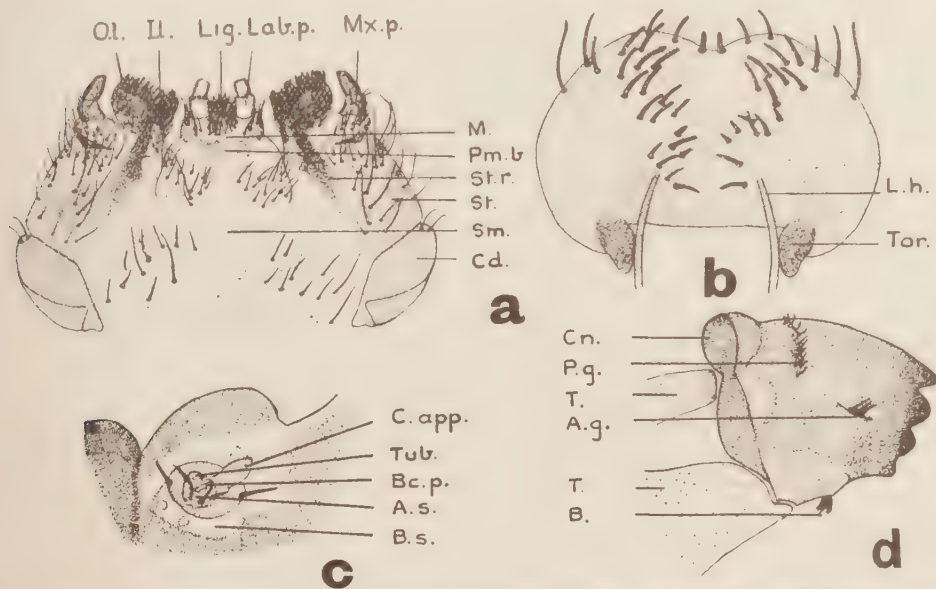


Fig. 6. *Ernobius mollis*, L.: a, maxillae and labium (x 90); b, labrum—ventral view (x 225); c, antenna (x 410); d, mandible—dorsal view (x 90).

The spiracles (fig. 5c) have but a short prolongation of the peritreme, about equal to that of *Xestobium*.

Notes.

Ernobius mollis is not a species of much economic importance, being found in coniferous timbers the bark of which has not been removed. The frass resembles that of *Xestobium* but the pellets are smaller and more spherical; they are white or brown or black, apparently depending on whether the larva has been eating sapwood or bark.

Perris¹⁵ says that the legs are four-segmented and spinules occur on the metathorax and all abdominals save the eighth; he gives a complete description. Erichson⁷ found spinules on the metathorax and first six abdominal segments only. Munro¹⁴ figures the larva with the spinules on the metathorax and all following segments; he also shows in another figure several setae on the anterior margin of the epistome. I could see no sign of paramedian chitinous marks on the epipharynx as mentioned by Böving.⁴

***Ptilinus pectinicornis*, L.**

The larva of *Ptilinus* does not conform to the general Anobiid type so precisely as do the three species already considered. The fully grown larva is about 7 mm. long and is noticeably curved posteriorly. The body is greatly swollen anteriorly in the thoracic region but not expanded at all posteriorly; in addition, the ventral surface is broader and flatter than in *Xestobium* with the result that the hypopleural folds are very prominent. Numerous short, erect, golden setae cover the larva being especially numerous on the head capsule and hypopleural folds. The subdivision of the thoracic segments into folds is rather more complex than in *Xestobium* as will be shown later.

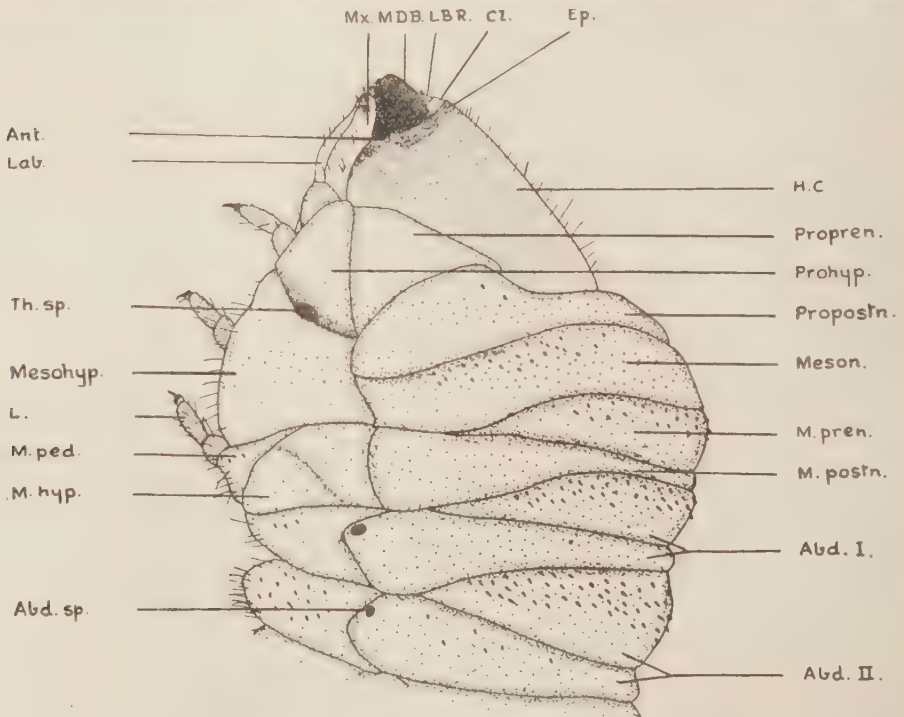


Fig. 7. *Ptilinus pectinicornis*, L.: fore-part of body (x 30).

Head-capsule.

The head (fig. 7) is set very obliquely in the prothorax and subtends an angle of 30° to 35° with the plane of the ventral surface of the thorax. As a result of this, the mouth-parts are directed more forwards than downwards, as is the case with the other Anobiids under consideration. Furthermore, the head-capsule when viewed from above is oval in outline instead of circular; the occipital foramen is similarly more elongate. Lastly, the anterior half of the head-capsule is markedly transversely rugose.

The epistome (fig. 8a) is linear and approximately six times as wide as long; the anterior margin is more concave than in the preceding species and has well-developed condyles laterally. The chitinised epistomal area is entirely devoid of setae.

The antennae (fig. 8e) are minute, retractile, distinctly two-segmented and situated in pits which are entirely surrounded by a narrow ring of chitin as in *Anobium*. The basal segment has a single oval, margined, transparent area and two setae laterally and there is a circular thickening round its upper margin. Distally, the basal segment bears a large, stalked, apically rounded appendix, and the second segment has two setae inserted in depressions of the upper surface. Both apical segment and appendix can be completely retracted into the basal segment.

No signs of ocelli were detected.

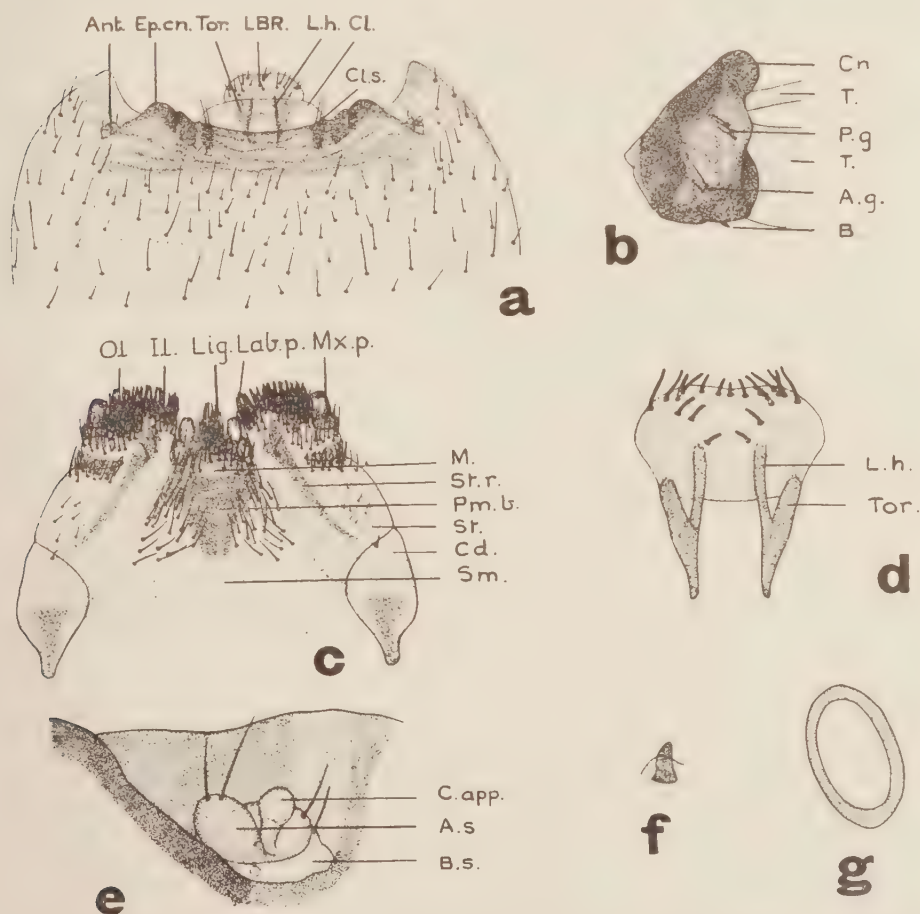


Fig. 8. *Ptilinus pectinicornis*, L.: a, epistome (x 90); b, mandible—dorsal view (x 90); c, maxillae and labium (x 90); d, labrum—ventral view (x 225); e, antenna (x 410); f, spinule (x 410); g, spiracle (x 410).

The clypeus (fig. 8a) is transverse, $3\frac{1}{2}$ times as wide as long, and has the margin broadly rounded. At its posterior angle on each side are two setae, which seem to be inserted on the line of junction of the clypeus and epistome.

Mouth-parts.

The labrum (fig. 8a, d) is $1\frac{1}{2}$ times as wide as long and has the anterior margin slightly indented, anterior angles very broadly rounded, sides convergent posteriorly and posterior margin more or less straight. The posterior angles are thickened and greatly produced posteriorly to form stout rod-like tormae which are fused with the labral hooks to give a bifurcate appearance. Dorsally (fig. 8a) the labrum is furnished on its anterior half with about eighteen short, scattered setae, and ventrally (fig. 8d) there is about the same number of rather slender truncate spines.

The mandibles (fig. 8b) are strongly chitinated, and have a prominent condyle and on their inner face one small tooth and a long sharp cutting edge. On the dorsal side is a posterior row of three and a more anterior group of two setae. Ventrally, is a brush of posteriorly directed hairs.

The maxillae (fig. 8c) are mostly membranous. The cardo is large and has only one instead of two articulating processes posteriorly: this single process is more strongly chitinated than the rest of the sclerite. One seta is present near the distal margin. The stipes is broad and bears a few small setae near the centre and a group of rather stronger ones anteriorly just below the insertion of the palp. The stipital rod is median, not marginal, in position and tapers off posteriorly: a pit and seta are present anteriorly. The three segments of the maxillary palp are short and broad. The basal segment is relatively large, united on its inner margin to the mala, and bears a number of setae on its anterior half: the middle segment has about six setae distally, and on the apical segment can be distinguished only a pit and a terminal group of sensory papillae. The mala is bilobed, the inner lobe being small and bearing about six strong spines anteriorly and a few fine setae posteriorly. The outer lobe is covered with a large number of strongly chitinated spines.

The labium (fig. 8c), except for the extent of the postmental chitination, is similar to that of the other Anobiids considered. The submentum is membranous and has a group of 20-24 setae anteriorly on either side of the postmental chitination, which in this species, is well marked and produced posteriorly in the form of an inverted blunt spear-head; this modification of the postmental band is peculiar to *Ptilinus*. At the front of the mentum is a transverse band of setae which is continuous with the setae on the ligula. The ligula is conical, with the apex rounded, and is covered with long, strong, anteriorly convergent spines. The palps are short and two-segmented.

Thorax.

The thoracic region (fig. 7) is very markedly swollen and the subdivision of the segments varies somewhat from the typical Anobiid type as characterised by *Xestobium*.

The prothorax is formed of a small, anterior lateral fold, the prenotal, which is entirely separated from its fellow by the deep dorsal excavation of the prothorax to accommodate the obliquely placed head. Behind this fold is a postnotal fold and below it on each side is the hypopleural. No pedal folds can be seen. Although spinules are normally wanting on the prothorax, in certain individual larvae one or two spinules have been noted on the postnotal fold.

The mesothorax has only a single fold dorsally which from its shape, size, position and the presence of spinules would appear to represent the united pre- and postnotal folds of this segment. Below it on either side of the body is a large quadrangular hypopleural fold; the pedal folds are also lacking from this segment. A lateral band of spinules 2-3 deep occurs on each side of the notal fold, but these bands do not extend on to the dorsal surface of the fold.

The metathorax is normal, comprising prenotal, postnotal, hypopleural and pedal folds apart from the sternal fold which, of course, is always present. A band of spinules 2-3 deep is present on the metathoracic prenotum, and an odd spinule may occur on the pedal folds.

A large spiracle can easily be seen in a depression between the pro- and mesothoracic hypopleural folds.

The legs are rather short and plump and are apparently but three-segmented, the trochanter and the tarsal segments not being distinguishable; the musculature is reduced and seems to correspond with that of the coxal, femoral and tibial segments of the *Nestobium* leg. A few short, very fine setae are scattered on the coxa and femur, but the tibia, which is the largest segment, is uniformly covered by numerous long setae, and bears terminally a strong sharply pointed claw and just above it a single stout spine.

Abdomen.

The folds of the abdominal segments can be made out quite easily and seen to follow the plan described for *Nestobium*. The tenth segment is small but distinct.

Spinules occur on the prenotal folds of the first eight abdominal segments in more or less oblique longitudinal rows with five or six spinules in each row; the spinules on the prenotal folds of the seventh and eighth are not so numerous as those on the preceding segments. They are also usually present in small numbers upon the postnotal folds of the third and fourth segments, and there may be also one or two spinules on the postnotum of the second abdominal segment. Numerous spinules appear on the hypopleural folds of segments 2-6 and one or two may sometimes be seen on the first abdominal hypopleural. On the ninth abdominal segment, spinules occur in a continuous band dorsally and laterally; none are present on the tenth. The spinules (fig. 8f) are very small, being short, blunt, and not very much curved.

The spiracles (fig. 8g) are different from those of other Anobiids in that they have no sign of the projection of the peritreme. The first pair are slightly larger than the rest of the abdominal spiracles.

Notes.

Ptilinus pectinicornis is not of very much economic importance, being found chiefly in dead trees, gate-posts, etc., although it is occasionally found in furniture; the woods most commonly attacked are beech, maple, willow, sycamore. The bore dust is characteristic, as it consists of very finely divided particles of wood which are not aggregated into faecal pellets.

Perris¹⁶ gives a full description of the larva and in it mentions that the antenna has at least three segments and that spinules are present on the mesothorax, metathorax, first four and the ninth abdominal segments. Munro¹⁴ states that spinules are present on all segments save the prothorax; his figure shows two setae on the anterior margin of the epistome and no clypeal setae. Böving⁴ says that the maxillary mala is simple, and not bilobed.

Priobium castaneum, F.

The larva of *Priobium* is of the same general form as that of *Nestobium* but is relatively more swollen posteriorly, the abdominal swelling being almost as great as the thoracic. The larva is curved, white to brownish in colour, and attains a length of about 8 mm. The body is covered with long, fine, erect, golden setae, and the head-capsule with similar but shorter setae.

Head-capsule.

In its general structure the head-capsule is similar to that of *Xestobium*. The epistome (fig. 9a) is very poorly chitinised and, except for the condyles, is almost indistinguishable in the living larva from the rest of the head-capsule. The slightly pigmented area is six times as wide as long. Along the anterior margin are about thirteen setae set in two rows and having their points of insertion in narrow transverse grooves on the surface of the epistome. Other setae are scattered over the epistomal area, but no groups are recognisable at the posterior angles.

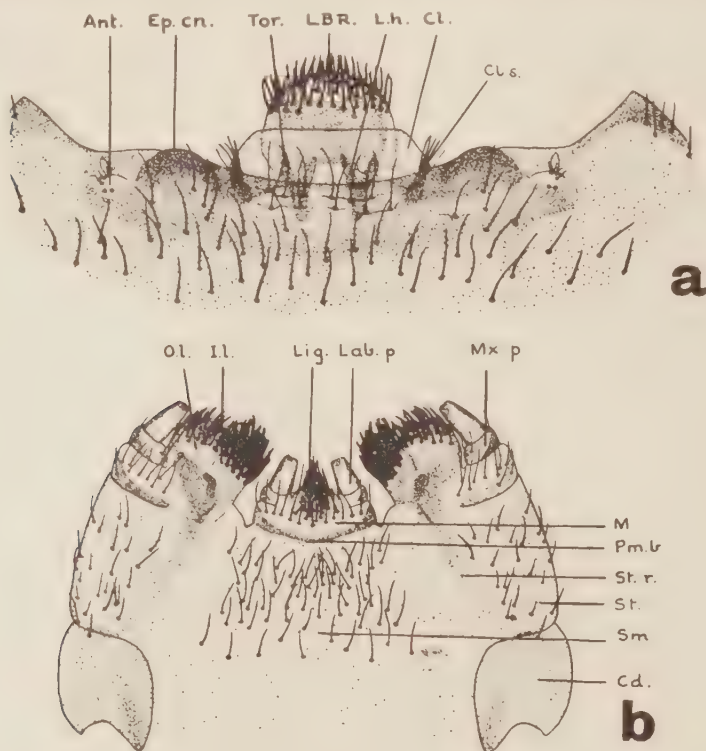


Fig. 9. *Priobium castaneum*, F.: a, epistome (x 90); b, maxillae and labium (x 90).

The antennae (fig. 10b) are capable of being retracted into the antennal pits and appear to be reduced to a single segment. This segment bears a large, conical, stalked appendix, a small tubular appendix and three setae, one of which is curiously expanded basally and is not inserted in the usual circular pit. Two margined, oval areas are apparent laterally.

There is a doubtful pigmented spot on each side of the head just behind the point of articulation of the mandibular condyle, which may represent a degenerate ocellus but no corneal thickening above it could be seen.

The clypeus (fig. 9a) is transverse, $3\frac{1}{2}$ times as wide as long, and has the anterior angles obtuse and rounded. The setae at each posterior angle are 2-4 in number.

Mouth-parts.

The labrum (figs. 9a, 10c) is nearly circular, like that of *Anobium*, and has the anterior edge entire or slightly indented. The posterior angles are thickened and produced to form large tormae, with which the labral hooks are almost entirely fused.

Dorsally (fig. 9a) there are numerous setae on the anterior third; ventrally (fig. 10c), the epipharynx bears a large number of flattened truncate spines, or, especially along the anterior margin, pointed, strongly recurved spines.

The mandibles (fig. 10a) are strong and rather variable in shape; the most usual type is a tridentate form resembling in outline that of *Anobium*. On the dorsal surface, the posterior group varies from two to six but usually has five setae; the more anterior group contains about six. The brush on the ventral surface is small and is formed of 6-9 setae.

The maxillae (fig. 9b) are of the usual type. The cardo is large, as broad as long, but little thickened at the posterior angles, and bears a single seta. The stipes is furnished with about twenty short setae; the stipital rod is well developed and has a distinct pit and seta distally. The basal segment of the palp is not separated on its

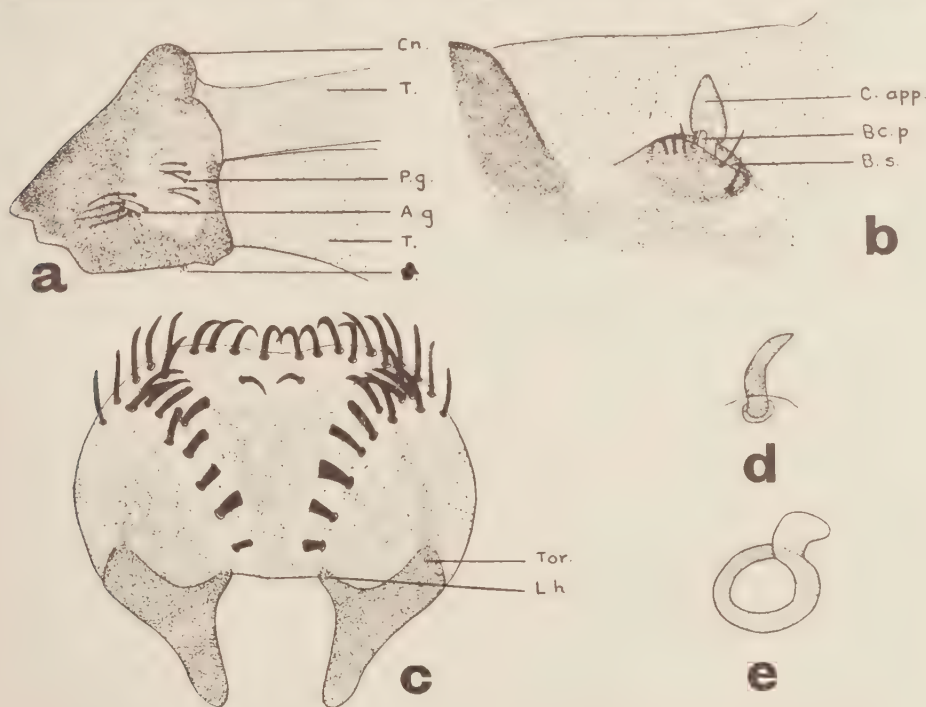


Fig. 10. *Priobium castaneum*, F.: a, mandible—dorsal view (x 90); b, antenna (x 410); c, labrum—ventral view (x 225); d, spinule (x 410); e, spiracle (x 410).

inner margin from the base of the mala and bears 6-10 setae. The middle segment is very short and bears three setae; the apical segment is elongate and has a single pit and a number of minute terminal sensory papillae. The mala is bilobed, the inner lobe being nearly as large as the outer and rendered very conspicuous since it is beset with about forty large, strong, darkly pigmented spines; the outer lobe is furnished in a similar fashion, but the spines are not quite so dense. At the base of the mala is a curious hook-like projection of the top of the stipital rod, which seems to be peculiar to this species.

The labium (fig. 9b) is of the normal type. The submental membrane is wide and has a large central group of setae. The mentum is bounded posteriorly by a narrow but definite postmental band. Across the mentum stretches a row of about

fourteen setae. The ligula is very short and broadly rounded, as in *Xestobium*, and is covered with numerous strong setae. The palps are two-segmented and bear no setae but have a group of minute sensory papillae apically.

Thorax.

The thorax of *Priobium* resembles that of *Anobium* in the plication of the segments, since the mesothoracic prenotal fold is divided by a transverse furrow, the anterior fold, however, being much smaller than the posterior. There are no spinules on the metathoracic prenotal fold. The thoracic spiracles appear as usual in a depression between the prothorax and mesothorax.

The legs are rather short and stout and are five-segmented. The trochanter is well marked and the coxa, trochanter, femur and tibia are all covered with a number of long, fine, brown setae. The small tarsal segment has two stout setae and a well developed claw, which is not quite terminal but arises from the segment somewhat laterally.

Abdomen.

The abdomen is composed of ten segments showing the various folds as in *Xestobium*.

Spinules occur on the prenotal folds of the first seven abdominal segments and latero-ventrally on the ninth; spinules are absent from the eighth and tenth segments. Those on the first seven segments occur in a single, sometimes a double, row and may be very few in number on the seventh segment. A typical spinule is shown in fig. 10*d*. It is long and slender and bent somewhat abruptly at about the middle.

The spiracles (fig. 10*e*) have a projection a little longer than half the width of the peritreme.

Notes.

Priobium castaneum is of no economic importance, being found most commonly boring in the dead parts of hawthorn. The frass is composed of cylindrical pellets with rounded ends very like that of *Anobium*, but the pellets are much larger.

Böving⁴ states in his key that the spinules are in rows three deep dorsally at the sagittal line on the first six abdominal segments and that the inner lobe of the maxillary mala is much smaller than the outer.

***Ochina ptinoides*, Marsh.**

The larva of *Ochina* resembles that of *Xestobium* but is less noticeably swollen thoracically and abdominally; its length is 5–6 mm. The body is white or yellowish in colour and is sparsely covered with fine golden setae; hairs are more numerous on the hypopleural folds, the ventral surface and the last three abdominal segments than elsewhere.

Head-capsule.

The head-capsule is similar to that of *Xestobium* but is rather less depressed dorso-ventrally and is hardly sunk in the prothorax to any extent; it is covered with numerous fine, short, erect, yellow setae.

The epistome (fig. 11*a*) is well defined, rectangular and about six times as wide as long. The articulating bosses for the mandibles are fairly prominent and darker in colour than the remainder of the epistomal chitination; between these prominences

the anterior margin of the epistome is slightly sinuous. No setae are present on the anterior half of the epistomal chitination but a few short scattered setae occur posteriorly. A very short, stout seta occurs at each side of the epistome just below the antennal pit; there are no groups of setae at the posterior angles.

The antennae (fig. 12*d*) are minute, two-segmented and lodged in pits which are protected posteriorly by lateral extensions of the epistomal chitination. In structure, they resemble the antennae of *Xestobium*. The basal segment is large and fleshy and bears one seta, a short, stalked, conical appendix and a short, well marked, cylindrical apical segment. So far as could be seen, this apical segment has three setae, the small basiconic appendix being absent. Two oval, margined areas were visible on the side of the basal segment. No signs of ocelli were detected.

The clypeus (fig. 11*a*) is transverse, nearly four times as wide as long, with the anterior margin straight and the anterior angles obtusely rounded. At each of its posterior angles is a group of six setae.

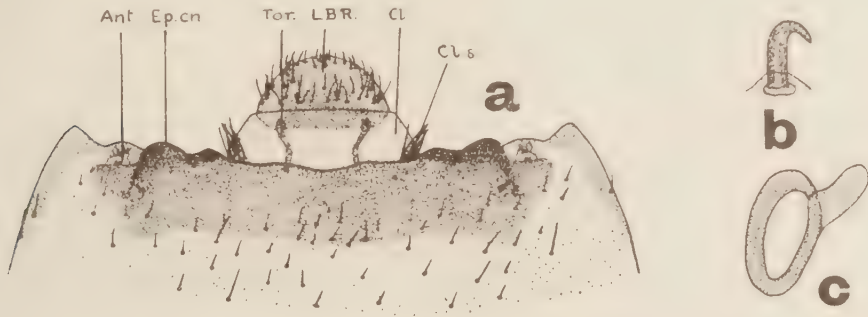


Fig. 11. *Ochina plinoides*, Marsh.: a, epistome (x 90); b, spinule (x 410); c, spiracle (x 410).

Mouth-parts.

The labrum (figs. 11*a*, 12*b*) is roughly semicircular in outline with the margin entire anteriorly. The posterior angles are thickened and greatly prolonged to form slender, curved, rod-like tormae; the labral hooks are entirely wanting. Fine short setae are present dorsally (fig. 11*a*) on the anterior half of the labrum, except for a central area which is bare. Ventrally, the disposition of the spines is shown in fig. 12*b*.

The mandibles (fig. 12*c*) are rather similar in outline to those of *Priobium* and *Anobium*; they are tridentate, but the innermost tooth is sometimes slightly notched to give the appearance of two teeth, making four in all. The posterior dorsal group consists of a row of seven setae and the anterior group comprises but two. Ventrally, is a brush of about 25 fairly long, recurved setae.

The maxillae (fig. 12*a*) are of the normal Anobiid pattern. The cardo is rather small, more strongly chitinated along its posterior margin, slightly emarginate on each side of the external posterior angle and bearing one or two setae ventrally at the external anterior angle. The stipes is broad and is furnished with about fourteen setae, four dorsally and ten ventrally. The stipital rod is poorly chitinated, tapers posteriorly and has the usual pit and seta near its anterior end. The palp is three-segmented with the basal and intermediate segments rather plump, and the terminal segment longer and more slender. The basal segment bears about ten setae on its poorly chitinated anterior half, the middle segment has two setae and two pits, and the apical segment has one pit and a terminal group of minute sensory papillae.

The submentum of the labium (fig. 12a) is membranous and bears ventrally a posterior row of 8–10 setae and anteriorly on either side of the middle line a group of about a dozen. The postmental band is narrow, straight and not very strongly chitinised. The mentum is produced anteriorly to form a short, broad, rounded ligula which is covered with a number of short, stout setae; a transverse band of setae occurs ventrally on the mentum. The labial palps are two-segmented, the basal segment being provided with a single seta anteriorly; the apical segment has a group of sensory papillae terminally.

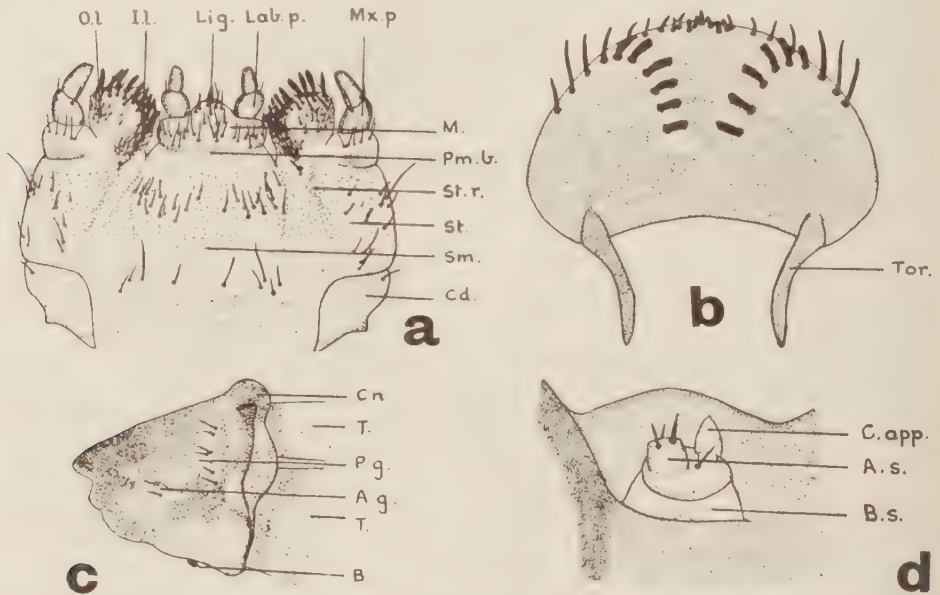


Fig. 12. *Ochina ptnoides*, Marsh.: a, maxillae and labium (x 90); b, labrum—ventral view (x 225); c, mandible—dorsal view (x 90); d, antenna (x 410).

Thorax.

The thorax is similar to that of *Xestobium*. The metathorax has on its prenotal fold a band of spinules in rows 3–4 deep near the middle line. The thoracic spiracles are large and situated in a shallow depression between the prothorax and the mesothorax.

The legs are well developed, distinctly five-segmented, and sparsely covered with fine setae. The tarsal segment ends in a sharp curved claw and has two or three bristles just below the claw.

Abdomen.

The tenth segment is moderately large and distinct; the rest of the abdomen corresponds to that of *Xestobium*.

Spinules occur in transverse bands on the prenotal folds of the first seven segments. On the first and second segments the bands are four spinules wide at the mid-dorsal line, segments 3–6 have bands 2–3 spinules wide, whilst on the seventh segment 4–9 spinules occur in a single row. In addition to these prenotal bands a lateral group of about a dozen spinules occurs on each side of the ninth segment and two groups of 10–15 each are present on the ventral surface of the tenth. The spinules are long,

sharp pointed, and either bent at right angles or recurved, hook-like, as in fig. 11*b* ; they can be seen to have a tubular cavity running up the centre.

The spiracles (fig. 11*c*) have a long projection equal in length to the shorter diameter of the elliptical peritreme.

Notes.

Ochina ptilinoides is a species of no economic importance, occurring only in dead and dry branches of ivy. The frass consists of cylindrical pellets with very abruptly and obtusely pointed ends, and although very similar to those of *Anobium* are definitely less fusiform.

No literature was found in which the larva of this insect was described.

Hedobia imperialis, L.

The larva closely resembles that of *Nestobium* but only reaches a length of about 6.5 mm. The colour is white or yellowish with darker head-capsule and brown mandibles and epistome. The body is thickly clothed with long, fine golden setae, as also is the head capsule, resembling in this respect the larva of *Sitodrepa*. The abdomen is curved and swollen to about the same extent as that of *Nestobium*, but is somewhat flatter ventrally.

Head-capsule.

The head-capsule is rugose and covered with long erect setae. It is distinctly flattened dorsally over an area a little greater than that covered by the epistomal chitinisation. The setae on this area are set in rather large and conspicuous pits.

The epistome (fig. 13*a*) is well chitinised and the chitinisation extends backwards in the form of a triangle as in *Ernobius*. The chitinised area is about $1\frac{1}{2}$ times as wide as long. The anterior margin is slightly concave and the condyles are prominent laterally. Just within the anterior edge is a single row, interrupted medially, of long, fine setae, 22-26 in number ; the bases of many of these setae are inserted in transverse grooves on the surface of the epistome. Apart from this row, the epistomal area is without setae on the anterior portion but densely covered posteriorly. There is an antennal group of 2-3 long setae on either side at the inner lateral margin of the chitinisation bordering the antennal pit.

The antennae (fig. 14*c*) are minute, retractile, and protected posteriorly by a ridge projecting from the lateral margin of the epistome ; this ridge makes observation of the structure of the antennae very difficult. So far as could be seen there is a large cushion-like basal segment with two oval, margined, lighter-coloured areas on it near the base. Apically, there are two setae, a slender, tubular basiconic process and a large and prominent stalked, conical appendix. No signs of an apical segment could be detected. No ocelli were to be seen.

The clypeus (fig. 13*a*) is transverse, a little more than three times as wide as long and has the anterior margin straight with the anterior angles obtuse and rounded.

Mouth-parts.

The labrum (figs. 13*a*, 14*a*) is almost semicircular with a slight indentation of the anterior margin. The posterior angles are thickened and produced posteriorly to form well marked tormae which are fused with the labral hooks. Dorsally (fig. 13*a*), the anterior half is thickly covered, except for a small central area, with strong brown setae the posterior of which are longer but not so stout as the anterior. Ventrally (fig. 14*a*), there is a large number of slender spines arranged along the anterior margin and in two or three rows on each side of the middle line ; these spines extend right back to the posterior margin of the labrum and one pair can be seen on the wall of the oesophagus.

The mandibles are tridentate (fig. 14*b*), the teeth being small but sharp, but this seems to vary somewhat in individual larvae. Dorsally, the posterior group contains about three long setae and the anterior group two short ones. Ventrally, is a brush consisting of about six relatively long setae.

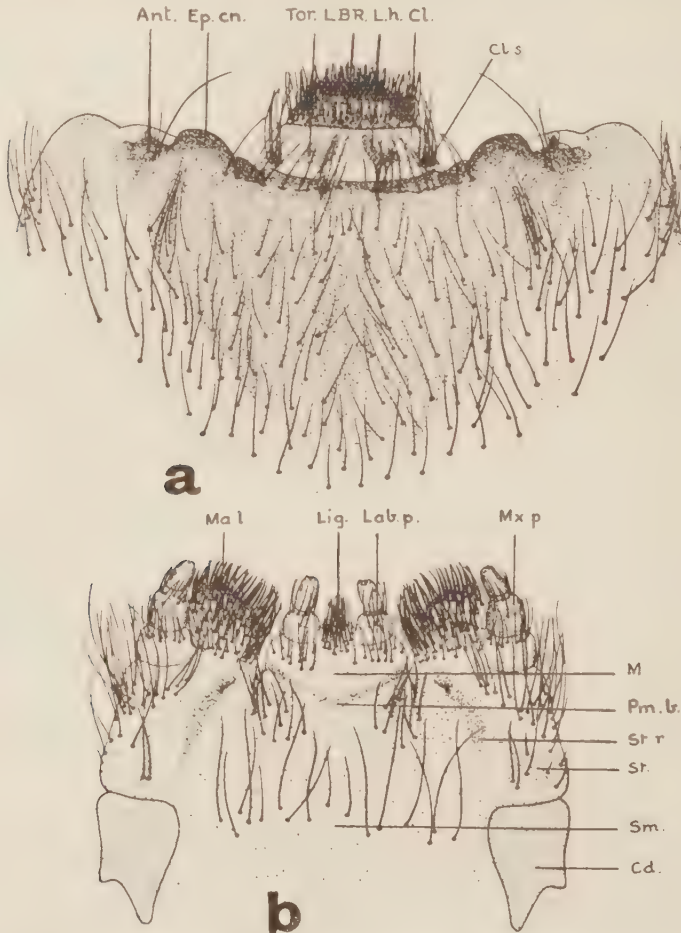


Fig. 13. *Hedobia imperialis*, L.: a, epistome (x 90); b, maxillae and labium (x 90).

The maxillae (fig. 13*b*) conform to the normal Anobiid type. The cardo is large, has the inner posterior angle markedly produced, and is devoid of setae. The stipes is beset on its outer margin and round the base of the palp with numerous very long fine setae; the stipital rod is poorly chitinised but has a distinct pit and seta near its apical end. The palp has the terminal segment relatively short when compared with the two lower segments. The basal and intermediate segments are furnished on their anterior halves with about ten setae each. The mala is apparently not divided into inner and outer lobes. Anteriorly, it is beset with a large group of long, slender spines, some of which are truncate, which extends posteriorly over the dorsal surface and merges with the stout setae occurring at the base of the mala. There is a greater concentration of spines and setae on the inner margin of the mala at the apex of the stipital rod which makes it appear at first sight as if an inner and outer lobe of the mala were present. On the ventral surface of the lobe are a large number of very fine, long setae.

The labium (fig. 13b) shows a broad submentum with a posterior row of about sixteen setae and two anterior groups of 12-18 setae each. The postmental band is narrow and broadly V-shaped posteriorly. The mentum is comparatively large and has a group of about ten long setae just below each palp. The ligula is short, rounded anteriorly and provided with numerous stout setae. The two-segmented labial palps are large, the basal segment bearing a number of setae and the apical segment having a prominent terminal group of sensory papillae.

Thorax.

The prothorax seems to resemble that of *Ptilinus*, for the prenatal and postnotal folds are distinct; furthermore, no pedal fold could be seen. The hypopleural is incompletely separated from the prenatal.

The mesothorax has the prenatal fold divided into two by a transverse furrow, the hypopleural is small and the pedal large. Spinules occur in a short dorsal band, 1-2 wide, on the posterior half of the mesoprenotal fold.

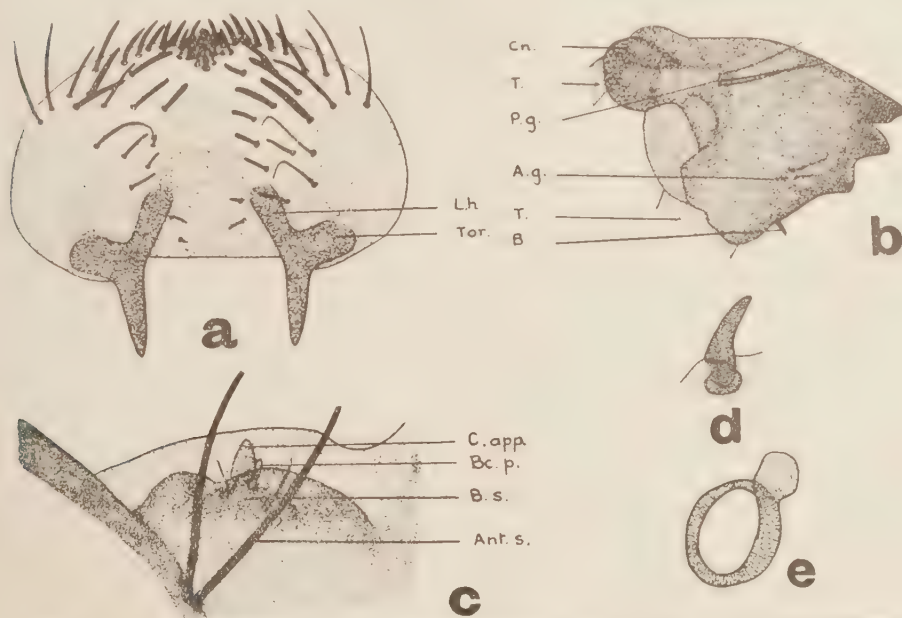


Fig. 14. *Hedobia imperialis*, L.: a, labrum—ventral view (x 225); b, mandible—dorsal view (x 90); c, antenna (x 90); d, spinule (x 410); e, spiracle (x 410).

The metathoracic segment is divided into folds in the normal way. Spinules are present in a band 2-3 wide medially on the prenatal fold and a few spinules, up to six have been observed, may occur laterally on the postnotal fold.

The thoracic spiracles between the prothorax and mesothorax are distinct although sunk in depressions.

The legs are long and four-segmented, no signs of the trochanter being evident. The coxa is very short, supported proximally by a chitinous framework and bears about five very short setae. The femur is elongate, about three times as long as broad, and has a few setae on it. The tibia is more slender and not quite so long as the femur and is furnished with a number of reddish brown setae which are as long as the

segment itself. The tarsal segment is larger than that found in any of the Anobiids so far mentioned being rather more than one-third as long as the tibia ; it has terminally a fine, straight, needle-pointed claw which is as long as or longer than the tarsus itself, and below the claw bears six stout spines. On the front legs the claws are stronger, greatly curved, and shorter than the tarsus, which bears 8-10 strong spines.

Abdomen.

The abdomen comprises ten distinct segments, the tenth being small and more or less restricted to the ventral surface of the body. The folds of the segments correspond to those of *Xestobium*, but the prenotals are larger in relation to the postnotals and the hypopleurals, especially those of the eighth segment, are more prominent.

Spinules occur on the prenotal folds of the first seven abdominal segments and in large numbers laterally on the ninth and dorsally on the tenth ; one or two spinules may be present laterally on the postnotal fold of the first segment and also on the prenotal of the eighth. On the first four segments the spinules are in rows 3-4 deep, on the fifth 5-6, on the sixth 3-5 deep medially, and on the seventh in a single row. The spinules are recognisable by the ridge present on them where they come through the skin as shown in fig. 14*d*. The wide bands of spinules on the fourth and fifth abdominal segments are very noticeable.

The spiracles (fig. 14*e*) have a projection about as large as that of *Priobium*.

Notes.

Hedobia imperialis has no economic importance, being found only in dead and rotten stumps and branches of woods such as birch and lime. The larva constructs a cocoon for pupation. The type of frass was not determined.

Bouché³ gives a description of the larva and says that the maxillary palp is five-segmented. This is amended to three-segmented by Buddeberg,⁵ who also states that spinules are present on the mesothorax, metathorax and all the abdominal segments. Böving⁴ reports that the epipharynx is densely covered with long hairs.

Sitodrepa panicea, L.

The larva of *Sitodrepa* is very similar in general form to that of *Xestobium* ; but it only attains a length of 5 mm. The body is white or yellowish in colour and is thickly beset with long, fine, erect, golden setae. The abdomen is normally curved ventrally but can be straightened to such an extent that the larva is just capable of progressing on a flat surface.

Head-capsule.

The head-capsule is fairly prominent and is distinguishable from those of the other larvae considered so far, except *Hedobia*, by reason of the relatively great length of the erect golden setae covering it dorsally.

The epistome (fig. 15*a*) is well chitinised, 5-6 times as wide as long and in general outline similar to that of *Anobium*. The anterior margin is somewhat concave between the lateral condyles, which are not very prominent. Along the anterior edge is a single row of 8-12 setae. Apart from these the anterior half of the epistomal chitinisation is lacking in setae ; long, fine setae are scattered over the posterior portion of the epistomal area. Laterally, on a level with the posterior margin of the antennal fossa, is a very distinct group of 4-6 long setae.

The antennae (fig. 15*c*) are minute, retractile and protected posteriorly by a lateral expansion of the epistome. The basal segment is large, fleshy and has two small, oval margined areas laterally. Apically, there are two setae, a very small basiconic

process, a very large, conspicuous elongate stalked conical appendix, which is somewhat pigmented and has a coarsely granular appearance, and finally in the centre is a small tubercle, bearing three short setae and possibly representing the remains of the apical segment.

On either side of the head, behind the inferior angle of the mandible is a slightly pigmented eye-spot.

The clypeus (fig. 15a) is transverse, four times as wide as long, with the anterior margin straight and anterior angles rounded and obtuse as in *Ochina*. At each of the posterior angles is a group of 5-7 long setae.

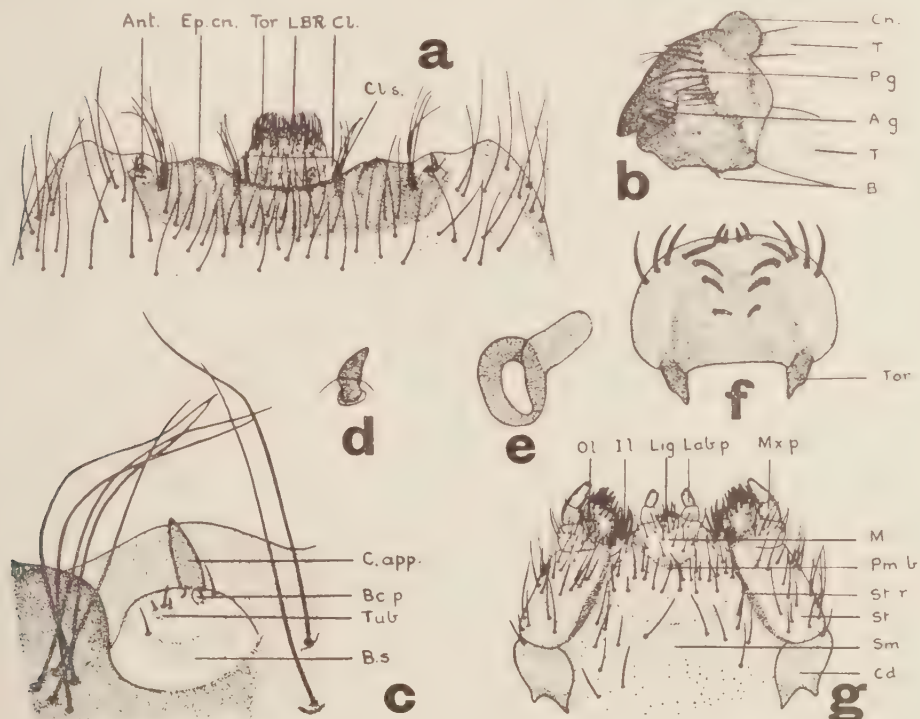


Fig. 15. *Sitodrepa panicea*, L.: a, epistome (x 90); b, mandible—dorsal view (x 90); c, antenna (x 410); d, spinule (x 410); e, spiracle (x 410); f, labrum—ventral view (x 225); g, maxillae and labium (x 90).

Mouth-parts.

The labrum (fig. 15a, f) is roughly elliptical with the anterior margin slightly indented and the posterior angles thickened and produced backwards to form short rod-like tormae; the labral hooks are entirely wanting. Dorsally (fig. 15a), the anterior half is covered by numerous long, fine setae and three pits occur in a transverse row just in front of the clypeal margin, as in *Anobium*. The ventral surface (fig. 15f) is furnished with two series of seven long curved spines and four small spines on the anterior margin.

The mandibles (fig. 15b) are short and tridentate; there is a very prominent apical tooth and below it is an elongate cutting edge which is notched to give the appearance of two more teeth. The condyle is relatively large. The posterior dorsal group is

formed of a row of about twelve long setae, and the anterior group contains about eight shorter setae; both groups are set well forward on the mandible. Ventrally, the brush of short, fine, recurved setae is set in a well marked depression.

The maxillae (fig. 15g) have a fairly small cardo which is deeply emarginate posteriorly, carries one seta at its external apical angle and is rather more strongly chitinised than the rest of the maxilla. The stipes, which is furnished with about twenty long setae, is demarcated on its inner side by the well developed stipital rod; this rod has a pit and seta near its upper end. The palp is three-segmented and comparatively elongate. The basal segment bears about ten setae dorsally and ventrally and is very poorly chitinised on its anterior two-thirds. The middle segment has two ventral setae and two pits only, and the more strongly chitinised apical segment has a single pit and a terminal group of small sensory papillae. The mala is divided into two lobes, the inner of which is about one-quarter the size of the outer and bears at its apex about five long, pointed spines, and more posteriorly there is a dorsal row of very fine setae extending from the base of the inner lobe across the base and up the outer edge of the outer lobe. This latter lobe has along its anterior margin a row of about nine slender spines with a few others irregularly placed ventrally on the anterior third.

The labium (fig. 15g), as in the other Anobiids, is membranous posteriorly. The submentum bears a posterior band of about fourteen scattered setae and an anterior group of about twenty. The postmental chitinisation takes the form of a narrow, obtusely V-shaped band. The mentum is provided with a few fine setae, as is the ligula, which is very short and rounded. The two-segmented labial palps bear no setae; the apical segment has the usual terminal group of sensory papillae.

Thorax.

The thorax is densely covered with long, fine, erect, golden setae. On the prothorax, the pedal folds seem to be wanting. The mesothoracic hypopleurals are not clearly marked off from the mesopostnotal but the pedal folds of this segment are distinct. The metahypopleurals are also very indistinctly marked off from the corresponding postnotal fold. Spinules usually occur on the prenotal of the meta-thorax but are very variable in number. Several larvae were examined which had no spinules present on this segment but some had only one or two, usually laterally, and a few had a single row of about eight widely separated.

The thoracic pair of spiracles is more anterior in position than is the case in *Xestobium* and is slightly larger than the abdominals.

The legs are comparatively long, slender and definitely five-segmented, and are terminated by a very elongate, sharply pointed claw. Strong reddish brown hairs occur on all the segments but are most numerous on the distal half of the tibia.

Abdomen.

The abdomen has ten distinct segments divided into folds, as in *Xestobium*. The hypopleural of the eighth segment is large and prominent; the ninth and tenth segments are covered very densely with long, fine, golden to reddish brown hairs.

Spinules are to be seen on the prenotal folds of the first eight abdominal segments and laterally on the ninth; the tenth segment is devoid of spinules. On the first six segments the spinules occur in bands two rows deep and in single rows or scattered on the seventh and eighth. The spinules are short and stout as shown in fig. 15d.

The spiracles (fig. 15e) have a projection which is not quite as long as the long axis of the oval peritreme.

Notes.

Sitodrepa panicca is a pest of great economic importance, and a good account of its damage is given by Zacher²⁹; it is not a wood borer but attacks most food materials and may do considerable injury to drugs.

Perris¹⁶ notes that no spinules occur beyond the sixth abdominal segment. Munro¹⁴ shows spinules on all the abdominal segments but none on the metathorax. Sharp²⁵ mentions that only one pair of spiracles, the prothoracic, could be detected. Janisch¹¹ gives some information on the variability of the number of spinules in individual larvae and mentions that the hairs on the head seem to possess a tactile function. Van Emden⁶ says in his key that spinules are absent from the eighth abdominal segment.

KEYS TO SPECIES.

As has already been mentioned, two types of key are desirable for the identification of larvae, one key for use with a low-powered binocular microscope or a powerful hand-lens and a second for use when mounted preparations are being dealt with and a higher-powered microscope can be employed. It is not always possible to construct a key for work with low powers, since there may not be a sufficient number of macroscopic characters by which the larvae may be differentiated. In the case of the eight species of ANOBIIDAE included in this paper, however, a key (Key I) has been constructed which has proved satisfactory with all the larvae so far tested. The second type of key (Key II) is easier to draw up owing to the large number of microscopic differences of structure between the various larvae. Key I is, of course, suitable for use with permanent preparations as well as living or preserved larvae.

The most important specific characters are the arrangement of the spinules, the extent of epistomal chitinisation, the chaetotaxy of the epistome, the form and number of the spines on the ventral surface of the labrum, and the presence, absence or fusion with the tormae of labral hooks. Characters which are sometimes difficult to see, such as the number of teeth and the chaetotaxy on the mandibles, have been avoided so far as possible; these characters are given in the text.

Key II is detailed so that a number of important alternative characters are given, but the characters are so arranged that the first in each list is the most important and can be used without recourse to the accessory characters if rapid determination of larvae is required.

KEY I—FOR WHOLE LARVAE.

- | | | |
|---|------------------------------------|---|
| 1. Spinules present on hypopleural folds of first six abdominal segments | <i>Ptilinus pectinicornis</i> , L. | |
| Spinules not present on hypopleural folds of first six abdominal segments | | 2 |
| 2. Spinules absent from ninth abdominal segment ... | <i>Anobium punctatum</i> , De G. | |
| Spinules present laterally on ninth abdominal segment ... | | 3 |
| 3. Epistomal chitinised area large and triangular or semicircular in outline | | 4 |
| Epistomal chitinised area small and linear or rectangular ... | | 5 |
| 4. Mesothoracic prenatal fold divided into two by a transverse furrow, the posterior portion provided with a short band of spinules | <i>Hedobia imperialis</i> , L. | |
| Mesothoracic prenatal fold not divided and not provided with spinules | <i>Ernobius mollis</i> , L. | |
| 5. Spinules in bands on first two abdominal segments in rows 4—5 deep at mid-dorsal line; spinules present on tenth abdominal segment ... | | 6 |
| Spinules in bands on first two abdominal segments in single or at most double rows at mid-dorsal line; spinules absent from tenth abdominal segment ... | | 7 |

- 6 Spinules in band on seventh abdominal segment in a row 2-3 deep at mid-dorsal line ; few spinules present on eighth abdominal segment
Xestobium rufovillosum, De G.
 Only a few spinules in single row on seventh abdominal segment ; none on eighth *Ochina ptinoides*, Marsh.
7. Setae on head-capsule very long and prominent ; a few spinules on pre-notal fold of eighth abdominal segment *Sitodrepa panicea*, L.
 Setae on head-capsule short and not very conspicuous ; no spinules on prenotal fold of eighth abdominal segment *Priobium castaneum*, F.

KEY II—FOR MOUNTED PREPARATIONS.

1. Epistomal chitinised area large and triangular or semicircular in outline ; epipharynx with at least 15 spines on either side of the middle line apart from the marginal spines ; projection of peritreme of spiracle not longer than one-half the width of the spiracle 2
 Epistomal chitinised area small and linear or rectangular ; epipharynx with less than 15 spines on either side of middle line apart from the marginal spines ; projection of peritreme varying in length 3
2. Setae present on anterior margin of epistome ; tormae fused with labral hooks ; maxillary mala not bilobed ; numerous strong spines present medially on anterior margin of epipharynx *Hedobia imperialis*, L.
 Setae absent from anterior margin of epistome ; tormae not fused with labral hooks ; maxillary mala bilobed ; very few spines present medially on anterior margin of epipharynx *Ernobius mollis*, L.
3. Postmental chitinisation large and produced posteriorly in the form of an inverted blunt spearhead ; epistome transversely rugose and without setae ; 2 setae on clypeus ; mandible with small tooth and long straight cutting edge ; spines on epipharynx very slender ; spinules very small and blunt *Ptilinus pectinicornis*, L.
 Postmental chitinisation bandlike ; epistome not transversely rugose ; mandibles with more than one tooth ; spines on epipharynx not very slender ; spinules relatively large and not blunt 4
4. Tormae and labral hooks not fused ; inner lobe of maxillary mala bearing one very large and strong spine and 2-3 more slender spines ; projection of peritreme of spiracles never more than one-half the width of the spiracle *Xestobium rufovillosum*, De G.
 Tormae and labral hooks fused or the latter absent ; inner lobe of maxillary mala without one very large spine but bearing a few or many slender spines ; projection of peritreme of spiracles at least as long as one-half the width of the spiracle 5
5. Setae (apart from setae at posterior angles of clypeus) absent or not more than 2 in number on the anterior half of the epistome 6
 At least 6 setae (apart from those at posterior angles of clypeus) on anterior half of the epistome 7
6. Labral hooks present and fused with the tormae ; 2 setae on anterior half of epistome ; 4 setae on clypeus ; double row of setae present medially on ligula ; stipital rod strongly developed ; antennae one-segmented ; all spinules only slightly curved ; projection of peritreme at least as long as spiracle *Anobium punctatum*, De G.
 Labral hooks absent ; no setae on anterior half of epistome ; 10-12 setae on clypeus ; setae on ligula irregularly placed ; stipital rod poorly developed ; antennae two-segmented ; many spinules greatly curved and hook-like ; projection of peritreme not as long as spiracle *Ochina ptinoides*, Marsh.

7. Labral hooks present and fused with tormae; inner lobe of maxillary mala nearly as large as outer lobe and armed with about 40 spines; setae of head-capsule fairly short and sparse; epipharynx with about 20 spines on either side of the middle line; spinules long and slender; projection of peritreme shorter than width of spiracle *Priobium castaneum*, F.
- Labral hooks absent; inner lobe of maxillary mala much smaller than outer lobe and armed with about 5 long spines; setae of head-capsule long and numerous; epipharynx with 7-10 spines on either side of the middle line; spinules short and stout; projection of peritreme as long or longer than width of spiracle *Sitodrepa panicea*, L.

Summary.

In this paper, an attempt has been made to describe the external morphology of eight species of larvae belonging to the family ANOBIIDAE with a view to constructing keys for the identification of these larvae and providing descriptions by which identification can be definitely confirmed. Two keys have been drawn up for use according to whether whole larvae or mounted preparations of parts of larvae are being examined. Notes have been added at the end of the description of each larva giving particulars as to its habitat and points for comparison from the descriptions of other workers.

One point of interest that arises from the foregoing descriptions is that *Hedobia*, which has usually in the past been classified as a member of the family PTINIDAE is definitely an Anobiid when the structure of the larva is considered.

In conclusion, I should like to thank Mr. R. S. Pearson, C.I.E., F.L.S., Director, Forest Products Research, for permission to publish this report.

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EXPLANATION OF LETTERING TO FIGS. 1-15.

Abd. I-X	= Abdominal segments	MDB.	= Mandible
Abd. sp.	= Abdominal spiracle	Mesohyp.	= Mesothoracic hypopleural fold
A.g.	= Anterior group of setae	Meson.	= Mesonotum
Ant.	= Antenna	Mesoth.	= Mesothorax
Ant. s.	= Antennal seta of epistome	Metath.	= Metathorax
A.s.	= Apical segment	M. hyp.	= Metathoracic hypopleural fold
B.	= Brush of setae	M. ped.	= Metathoracic pedal fold
Bc. p.	= Basiconic process	M. postn.	= Metathoracic postnotal fold
B.s.	= Basal segment	M. pren.	= Metathoracic prenotal fold
C.	= Claw	Mx.	= Maxilla
C. app.	= Conical appendix	Mx. p.	= Maxillary palp
Cd.	= Cardo	O. 1.	= Outer lobe of mala
Cl.	= Clypeus	Occ. for.	= Occipital foramen
Cl. s.	= Clypeal setae	P. g.	= Posterior group of setae
Cn.	= Condyle	Pm. b.	= Postmental band
Cx.	= Coxa	Postn.	= Postnotal fold
Ep.	= Epistome	Pren.	= Prenotal fold
Ep. cn.	= Epistomal condyle	Prohyp.	= Prothoracic hypopleural fold
Epc. s.	= Epicranial suture	Proped.	= Prothoracic pedal fold
Fe.	= Femur	Propostn.	= Prothoracic postnotal fold
Gen.	= Gena	Propren.	= Prothoracic prenotal fold
Gen. foss.	= Genal fossa	Proth.	= Prothorax
Gul.	= Gula	Sep.	= Septum
Gul. 1.	= Gular lobe	Sm.	= Submentum
Gul. t.	= Gular tubercle	Spin.	= Spinule
H.C.	= Head capsule	St.	= Stipes
Hyp.	= Hypopleural fold	St. r.	= Stipital rod
I. 1	= Inner lobe of mala	Stn.	= Sternal fold
L.	= Leg	T.	= Tendon
Lab.	= Labium	Tar.	= Tarsus
Lab. p.	= Labial palp	Th. sp.	= Thoracic spiracle
LBR.	= Labrum	Tib.	= Tibia
L. h.	= Labral hook	Tor.	= Torma
Lig.	= Ligula	Tr.	= Trochanter
M.	= Mentum	Tub.	= Tubercle
Ma. 1.	= Malar lobe		

SOME TRAPS FOR TSETSE-FLIES.

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(PLATES I-III.)

A. Introduction.

Much attention has lately been drawn to the question of trapping tsetse-flies, owing to the invention by Mr. R. H. T. P. Harris of a trap which has made spectacular catches of *Glossina pallidipes* in Zululand.

The writer as long ago as 1922 made use of oblong screens (p. 73 and Pl. i, fig. 1) of hide, hessian or cloth, as artificial bait for the attraction and catching of tsetse-flies; the insects were either caught with nets when they settled on the screens or trapped on them by means of bird-lime. The flies settle on these bait screens for long together, if undisturbed, and normally with their heads upwards if they are hungry. They move about, probe, and trend interruptedly to the top, the screens being particularly attractive to the females.

From late 1930, spurred actually at first by a trap designed in Mauritius for catching *Stomoxys*, we began to experiment in turning our screens into traps by placing a "non-return" wire gauze catching-cage along the top margin to intercept the flies that arrived there, the screen running up a little between the converging gauze strips. Even this simple form (the "PS" or "Plain Screen" trap, p. 75 and Pl. i, fig. 2) caught a number of *Glossina morsitans* and *swynnertoni*, our two most important tsetse-flies. In the case of *palpalis*, during a trial for two days only, this trap caught no less than 361 flies. Our early traps were less satisfactory than this for *morsitans* and *swynnertoni*, but a Harris trap that we tried was even less efficient, merely attracting in the main such *pallidipes* as happened to be present. This latter trap is based essentially on the principle that the flies are attracted into a dark chamber and led on into a light-admitting trap from which they cannot return, a principle which had been utilised in the Mauritius trap and in the crinoline trap for mosquitos.

Our own traps were based on quite a different principle, namely, the attraction afforded by a screen, and as this method seemed to hold higher promise for the flies with which we were chiefly concerned, we continued to develop it, while appreciating the valuable lead which Mr. Harris had given to the system of trapping as a control measure.

Dr. C. H. N. Jackson, our Survey Entomologist, handled all the earlier spade work on our catching-cage traps and, in relation to *morsitans* and especially *swynnertoni*, made a considerable advance. His ultimate design is known as the "JS" or "Jackson single-screen" trap forms J, M and N. An even better development of this is the "JV" trap, described on p. 76 (Diagram 3, figs. 12, 13; Pl. i, fig. 3, right). Both were the result of his special attempt to produce a trap in which shade should be reduced to vanishing point. He had, however, already done much experimenting with loose hanging awnings of various lengths and materials.

The writer took the work up at this point and, building on Jackson's basis, developed the "SS" or "Single-screen" awning trap (Diagram 1; Pl. i, fig. 4), which is excellent for *palpalis* and *pallidipes*; the "SY" trap, which is better (but still very imperfect) for *morsitans* and especially *swynnertoni*, and less good for *palpalis* and *pallidipes* (Diagram 3, figs. 5, 6); certain circular traps on the screen

principle ; the scent traps (Pl. ii, fig. 4 ; Pl. iii, fig. 3), which are far better than any other, though the use of animal baits presents obvious difficulties ; the " Roller " or " SR " screen traps or " moving staircase for tsetse-flies " with one and two rollers respectively (the latter suggested by Mr. S. Napier-Bax, our Senior Field Experiment Officer) ; and, finally, with Mr. H. H. Manson, Electrical Engineer to the Railways, the Electric Screen trap (Diagram 4 ; Pl. ii, fig. 3). Mr. J. Y. Moggridge (Field Experiment Officer) carried out very efficiently the later trials of some of these traps and invented a catching-cage trap on a further new principle. This has not yet been developed.

In addition to these, two new traps of the writer's that are not on the screen principle are described in this paper, and the list would not be complete without mention of a most promising pupa-trap, which is the cheapest of all our traps, costing a few cents only, that has been invented by Dr. T. A. M. Nash, second Entomologist to the Department. He will publish the details of this himself.

We have not been able to experiment for sufficiently long in dense fly of a species really responsive to traps (e.g., *pallidipes* or *palpalis*) to be able to give very striking figures ; our good *morsitans* trap (the " SR ") is too recent in any case. It has been thought well to publish, nevertheless, at this stage descriptions of each of our chief types of traps, both successful and less successful, well tried and less well tried, so as to place freely at the disposal of other workers on tsetse a number of ideas as to tsetse-traps on which they may try to improve. Many heads are better than few.

Having, by the favour of the respective investigators and their Governments, seen something of the trapping experiments in Zululand, Southern Rhodesia and Uganda, the writer would like to convey his very warm thanks for their kindness to those Governments and to Messrs. R. H. T. P. Harris (Director of Tsetse Control Operations, Natal), R. W. Jack (Chief Entomologist of Southern Rhodesia), W. F. Poulton (Director of Veterinary Services, Uganda), J. R. P. Postlethwaite (Provincial Commissioner, Buganda), and C. W. Chorley (in executive charge of the work on the Sesse Islands under the Provincial Commissioner). Co-operative experimentation in trapping is being initiated also between Kenya Colony and ourselves. The writer is indebted to the Director of Medical Services, Kenya, Dr. J. L. Gilks, and to the Medical Entomologist, Mr. C. B. Symes, for a most interesting and productive trapping expedition in Kavirondo. He is indebted also to Mr. R. Grantham, for his kindness in taking some excellent photographs of the traps and to Mr. L. J. Martin, District Engineer, Railways, Tanganyika, for useful advice on propellers, to Messrs. L. L. R. Buckland (Senior Assistant Engineer), R. T. Swales (Draughtsman) and E. Hooper (Workshop Superintendent), all of the Public Works Department, for their assistance ; and very especially to Mr. H. H. Manson (Electrical Engineer, Railways), for his enthusiastic aid over the electric trap ; and Mr. G. Rosch, Reclamation Assistant in the writer's department, for his keenness, hard work and resourcefulness in the construction of the long series of experimental traps from which present results are emerging. Others to whom the writer is indebted have been or will be mentioned in the course of this paper.

Mr. C. W. Chorley, mentioned above, is doing some admirable experimental trapping of *G. palpalis* on Nsadzi Island, combined with most useful observations.

B. Insect Traps based on Phototropism.

The following may be selected for mention :—

(a) The moth trap used by collectors, in which the insects are attracted from the natural darkness of night past the transparent non-return gateway by an artificial light placed behind it.

(b) The Mauritius biting-fly trap, in which the flies are conveyed to a darkened chamber by means of live animals driven in with the insects upon them and through a partition of leafy branches which brush the flies off them.

(c) The "revolving drum" trap for the house-fly, in which the insect, being diurnal, is again conveyed first into darkness, then into sight of light, but by mechanical means, a brush (or board) being used also as in the Mauritius trap.

(d) The "blue-bottle" traps used in latrines, in which the flies (or their parents) are attracted into the dark chamber provided by the latrine and in which the attraction is scent.

(e) The "crinoline" trap for mosquitos, long in use, in which the appearance of the trap and its darkened chamber are themselves the attraction to the insects, which afterwards go to the light admitted through a glass jar in the top of the trap.

(f) The Harris trap for tsetse-flies, which is extremely similar to (e), but in which the dark chamber is four-sided instead of round and depends from a platform of wood or galvanised iron (Pl. i, fig. 3, left).

In the first of these traps, the insects, being purely nocturnal, are in darkness already. All that is necessary is to provide a light. In the other five the insects are caught in the daylight, and it is the darkness that is artificially provided; the daylight, shining through an opening in the dark chamber, or by means of a mechanically produced alternation in the case of the drum trap, replaces the lamp. In all these traps also the insects definitely pass or are carried *inside* the darkened chamber, from which they are attracted by light into the trap, with, in two instances, a "brush" to help to dislodge them.

G. Principle and Construction of the Screen Traps.

Our screen traps are plain screens with a catching-cage on the top, or are developed therefrom. The flies move up *outside* the screen, whether it is simple, Y-shaped at the top, V-shaped, cylindrical and revolving, or box-shaped (to contain an animal—the "SU" traps). If there *is* a chamber, as in the SU trap, the flies do not enter it. Their progress, if they are hungry, tends (as stated already) to be upward in any case, and we take advantage of that; but as this movement is normally subject to many interruptions and, therefore slow and uncertain, it is further directed and hastened by *guides*, from less pleasing colour or texture to more pleasing, from (say) hessian to grey cotton cloth and thence to black woollen cloth, from an exposed screen to a strip of shade, until the flies are left finally near the top of the screen, already inside or close to the converging strips of the cage and with the one-way aperture an inch or two only above them.

When they get to this point on one of our cageless screens their usual next action is a short movement or flight to another part of the screen. When they are on a cage-bearing screen, this next movement, when attempted, is baffled. It takes them against the slanting gauze of the aperture of the cage, and thence they buzz and bang into the latter through the opening. They often stay near the top of the screen probing for quite a time, even with the mid-day sun shining on them, before they go to the catching cage.

In their general stay on the screen, which may last half an hour, they are constantly shifting short distances, and it has been definitely observed that they move from shadow to shadow and light to light far more frequently than they do from the one to the other. This latter alternation of movement, which some of the other traps bring about artificially, does not necessarily occur either in nature or here.

In our traps it is a matter of a natural upward trend and (or) *graded attractants*—of colour, texture and shade—till the flies are at last in the cage; and as shown earlier, even the shade-strip, though attractive, is by no means always essential. In all the other traps mentioned it is a matter of insects already in relative darkness, or plunged or attracted into relative darkness, responding by a positive phototropism to a brilliant light that contrasts with that darkness. In our traps this principle seems likely to operate appreciably only when the awnings hang down and converge towards the screen, but observation suggests that even then it has little or no effect.

The Harris trap is a platform "from which, extending downwardly" (to quote the patent specification) "is arranged a four-sided framework" of opaque material forming a chamber. On the platform is placed a catching cage, and an opening in the platform coincides with the lower edge of the cage.

Our traps have no platform and no sides, and above all, the great feature on which their effective catching primarily depends, namely the *screen*, is completely lacking in the Harris trap, as are our colour-attractions. Two experiments were carried out by Mr. Moggridge in which the awnings of the writer's SSB trap, with a catching cage on the top and closed at the ends (Diagram 3, fig. 7) but with no screen, were tested against the same trap complete with screen. The effect of the omission of the screen was most striking:—

Experiment 1.

SS 6ft., with screen, 238 flies (189 *pallidipes*, 49 *swynnertoni*)
 SS 6ft., without screen, 12 flies (10 *pallidipes*, 2 *swynnertoni*)

Experiment 2.

SS 4ft., with screen, 59 flies (*pallidipes*)
 SS 4ft., no screen, 1 fly (*pallidipes*)

It will be seen below that Manson's electric screen (Pl. ii, fig. 3) and Moggridge's trap (Diagram 3, fig. 18) are each different in principle from any other trap mentioned in this paper. The SR traps (Diagram 3, fig. 14) in which the expanded top of the screen of the SY trap, triangular in section, becomes round and revolves, carrying the flies that normally stop short of the catching cage into the latter, and the BSR (Diagram 3, fig. 16), in which there are two of these rollers, round which the whole screen climbs, resemble the Japanese house-fly trap in the fact of revolving and the Japanese and Mauritius traps in the fact that the flies are brushed or knocked off. In other respects—non-use of darkness, nature of bait, nature of motive agency and general details—they differ completely.

In two more of our traps, not screen traps, the flies do enter a darkened chamber, but each is in essential respects very different from the traps already worked on this principle.

D. Essentials for successful Trapping.

1. A trap, to be useful, must be readily perceived by the fly and must catch nearly all of the flies that perceive it. To do this latter it must (a) draw them to it from the point of perception, (b) hold their attention when they arrive, and (c) capture them.

2. It must still do these things in periods of the year when, normally, the flies are not hungry. At least it must do so for so many months in the year as to make trapping really exterminative.

3. Additionally, individuals out of the collection of traps set out in an area must be perceived by all the flies in that area—or by their descendants within a reasonable time. To avoid the expense of an innumerable army of traps the traps must range through the flies, as the game does, or the flies range to the traps.

4. Alternatively or additionally, the fly must be concentrated or concentrable, as regards its ranging or stationary habits, in relatively few sites in the general area attacked. These sites must also be readily recognisable by the trapper; without them, the expense will again be prohibitive through the need for supplying a veritable army of traps.

5. The trap must be as cheap as possible.

6. It must be sufficiently robust and easily transportable.

7. It must be capable of working, unvisited, for, say, a fortnight at a time.

8. Its material must be so recognisable that natives that steal it will be readily convicted ; it will be an advantage also if it is not too attractive to carnivora ; and it must be protected from the grass fires.

It should be noted in this connection (*a*) that some flies (*pallidipes* and *palpalis*) are very highly trappable by any reasonable trap, while others (as *morsitans* and *sawynnerloni*) are more refractory ; (*b*) that appearance, movement and scent are the three things by which, so far, we have found we can attract tsetse-flies ; (*c*) that colours and fabrics can be used also to draw the flies into the trap when they arrive (scent may actually come into this category) ; (*d*) that during the rains and the whole of the earlier dry season the female flies especially show themselves, even to traps, in very inadequate numbers ; (*e*) that of the flies that come to the traps the non-hungry individuals settle and play about on the outside of the trap and do not go in ; the importance of trapping these flies is more than doubtful, however, as they are nearly all males ; (*f*) that one fly (*palpalis*) has a highly concentrated general habitat, but that those of *morsitans*, *sawynnerloni* and *pallidipes* cover such large and even enormous areas that it is only if we can confine attack to limited spots in those areas, and yet reach the whole fly population, that we can hope to succeed ; (*g*) that this hope lies, nevertheless, in two things :—(i) the fact that the flies do concentrate, seasonally or for feeding, in recognisable spots, though these are still far too many, in numerous places too diffuse, and also liable to be thrown out of use by abundance of food in the general bush habitat ; (ii) the fact that flies will come to paths in some numbers and that Dr. Nash has shown, for *G. morsitans*, that by supplying a convergence of paths to a well-selected centre we can produce at that centre a concentration of flies that apparently have followed those paths.

As regards paragraph 8 above, it may be stated (*a*) that one of our traps was torn to pieces by a lion (annoyed probably by his mistake) and that this may happen more often when scent comes more into the picture ; another trap (in Kenya) was destroyed by an elephant ; (*b*) that one batch of our traps, thought to be safe, was destroyed by fire last year, fires in some of the fly belts being exceedingly fierce and the flames flying far ; (*c*) that thefts of the hessian by natives have taken place—in one locality persistently ; the addition of indelible broad arrows to the material is contemplated.

That elephants may not always be so unkind to our traps as the incident mentioned implies is suggested by the fact that the writer, at Kilosa, hung a trap between two large trees which were so close together that elephants used nightly to rub both sides of their bellies at once on them. They gave up this practice while the trap remained in position, though they continued to drink at the pool one yard away.

E. The Original Catching Screen (Diagram 3, figs. 1, 2 ; Pl. i, fig. 1).

On our original screens, made of khaki cloth, hessian or hide, bird-lime was used as the catching agent. The traps were either set up in the bush (attracting visually only) or were attached to the backs of cars, walkers or riders of bicycles. These possibly attracted olfactorily also.

At first, in 1922, the writer made some of the "bush" screens as animal silhouettes, but he soon found a mere oblong to be all that was necessary (Pl. i, fig. 1). A revolving screen was also made at that time (Dr. J. O. Shircore's suggestion), as was a "running deer." The former was later turned into a revolving catching-cage trap. Later the writer added shadow strips to the plain oblong screen, making this into the T-screen (Diagram 3, fig. 2).

On cars and bicyclists limed screens were effective ; on stationary and slow-moving objects far less so, the flies constantly veering off before landing. They had time, presumably, to be deterred by the sight (wet appearance ?) or smell of the bird-lime. Experiment by Jackson showed very definitely that a boy could catch more flies with a net and no screen than by means of a bird-limed screen.

Another experiment, by H. M. Lloyd, our fourth Entomologist, proved the fact that two small boys carrying one of our hessian screens and catching off it with nets are more effective than the same boys catching off themselves, the ground and each other. In this experiment the screen and the screen-less catchers were used on alternate days and the results were as follows :— (a) The number of *swynnertoni* was raised by 49·7% and the number of *pallidipes* by 225·9% ; (b) the female percentage of *swynnertoni* was raised from 17·4% to 26·0% and that of *pallidipes* from 27·8% to 55·8% ; (c) the actual number of female *swynnertoni* was raised by 110·3% and the number of female *pallidipes* by 320·0% ; it should be noted that for practical purposes it is not the female percentage that matters, for this may result merely from taking few males, but the *total numbers* of females taken by any contrivance ; (d) the number of pregnant *swynnertoni* taken with screens was 114 as opposed to 6 without ; and the number of pregnant *pallidipes* taken with screens was 6 as opposed to 1 only without.

The next point to be tested was colour. Screens of cloth of various colours were pitted by Lloyd against each other over a number of days. The results were as follows :—

	♂	♀	Total	Female per cent.	Per cent. increase in the number of ♀♀ on various cloth screens over hessian
Dark grey blanket ...	101	219	320	68·4	133·8
Medium grey blanket ...	106	175	281	62·3	86·2
Orange brown cloth ...	99	167	266	62·8	77·7
Light grey blanket ...	105	152	257	59·1	61·7
Black cloth ...	95	146	241	60·6	55·3
Hessian ...	99	94	193	48·7	—

The actual number of males appears not to be affected by the colour of the screen, whereas a dark grey screen seems to be far more attractive to females than any other colour that was tested.

The effect of the shadow strip was tested by Lloyd as well. T-shaped screens in which dark grey blanket connected the arms of the T with its tail and formed a concave curve in between (for convenience of catching) were tested against flat dark grey blanket screens. Using the T-screen the number of females taken was greater by 36·6% than when using the plain flat screen. The number of males was also raised.

As a result of these experiments Lloyd arrived at the following conclusions :—

(i) Portable moving screens raise the number of males and females caught, the latter notably ; (ii) they raise the female percentage ; (iii) they raise the pregnant female percentage ; (iv) a dark grey colour is more attractive to female flies than medium grey, orange-brown, light grey, black, and especially hessian ;* (v) a T-shaped screen, incurving or tapering from the arms of the T down to its stem, attracts more males and females than does a flat screen.

The "hand-catching screen" is the most effective of all the traps we have tried and is in daily use by us. The net, in smart hands, is a much surer weapon than a catching-cage, and the hand-catching screen catches nearly every fly that comes to it. The progressive movement attracts the flies from a distance, the screen possibly

*This does not conflict with the fact that, at very close quarters, the most attractive part of the screen of a catching-cage trap is the black strip at the top. This at least appears to apply to *pallidipes*, *palpalis* and *swynnertoni*. There have been indications that *morsitans* prefers grey even here.

attracts also by scent such flies as are ready to feed on man, whether scent be used by tsetse at long range or close, and, guided by its bearers, this trap actually *ranges*, *seeking out* the fly. The addition of the scent of a beast would improve it further.

Combined with cattle-bait, a grey screen tended to draw off to itself the flies that came to the latter, rendering these more easily caught. By its oblong shape and grey colour the hand-catching trap has, in addition, the attraction of a catching-cage screen trap and so brings in the females which otherwise would not have appeared to the natives. In this connection Jackson has interestingly shown that when the catch with stationary traps is exceedingly low, as with *G. swynnertoni* in January, fly-boys may be taking almost entirely males, yet have in the following swarm a large number of unobserved females, which, when a stationary trap is approached, fly to its screen and are seen. A trap that was experimentally "fed" by fly-boys walking up to it caught 15 females and 15 males. Fly-boys in the same area by themselves took 211 males and only 2 females in 3½ hours. During another hour in the same area and time two stationary traps were carried. These took 9 females.

Actually, owing to this habit of the females, it is exceedingly difficult ever to be sure that de-flying by hand-catching unaided by screens is complete. The most important part of the tsetse population is probably being missed.

F. Stationary, Swinging or Revolving Screen Traps that attract visually only.

1. *The Plain Screen Trap* ("PS" : Diagram 3, fig. 3, and Pl. i, fig. 2).

In this the screen usually simply hangs from the catching-cage and is stiffened by a framework of rods. Its upper margin preferably enters the non-return passage into the cage to within an inch or two of the non-return aperture. This was tried early by Jackson and caught *swynnertoni* and *morsitans* in small numbers. Tried by the writer against *palpalis* on Lake Victoria in the form of his adjustable "SS" trap (see below) with the hessian awning raised vertically right out of the way, against the sides of the catching cage (the sides of which were therefore opaque), it caught 361 flies in two days as narrated already. Tried briefly end to end with an "SSB" trap near Shinyanga, where both *pallidipes* and *swynnertoni* were present, the "PS" caught practically only the latter fly, while the "SS" trap (shadier) caught practically only *pallidipes*. The "PS" trap in this case was an "SSB" with the awnings removed.

2. *The Jackson Single Screen Trap* ("JS" : Diagram 3, fig. 12).

In this a gauze guard depends from each side of the opening in the bottom of the catching-cage or from the sides of the catching-cage of a "PS" trap for two or three inches, then bends in to the screen. Between it and the screen a space of, say, two inches is left. Horizontally covering the hessian opposite this space we have latterly added a strip of black cloth sewn to the screen, part of it showing below the guard, the rest being above it.

G. morsitans and *swynnertoni* have a habit, mentioned already, when they reach a high point on the screen, of flying back by the way they came instead of flying to the opening above them; hence the guard. It has partly achieved its object, though if brought in too close the flies leave on reaching it. There are actually three varieties of this trap, as follows:—

(a) Jackson's M trap. The catching cage is a half petrol box and the gauze guards depend from its sides and then turn in as described. Admitting (as it did) plenty of light it was best for *swynnertoni* and only moderate for *morsitans*. It was beaten in a short trial by a Harris trap, catching about half as many *morsitans* as the latter when the traps were not being fed by a lorry.

(b) His J trap (Diagram 3, fig. 12), with a full-depth petrol box or catching cage, which is shadier and therefore less suitable for *swynnertoni*, but better for *morsitans*. The guards go straight in at right-angles from the bottom of the sides of the petrol box. The full depth may not be necessary.

(c) His N trap, with an all-gauze catching cage, a wooden connection between the outer corner of this and the guard, and the latter coming in thence horizontally towards the screen. The screen *slanted*. Good for *swynnertoni* only.

In all these traps a grey blanket was used as a screen and it was found that the flies moved up light grey better than dark grey, the latter holding their attention too well. All caught *pallidipes* badly. All were tried in the rains or early dry season, so caught no great numbers, yet did quite well for the time of year. The cost for material and making each trap was estimated at about 9s., this allowing for 3 petrol boxes, or a length of nearly 6 ft.

The variety used by the writer—all-gauze cage and all-gauze dependent screen has not been so good as the "JV" trap for *pallidipes* or *swynnertoni*.

3. The Jackson V-trap ("JV": Diagram 3, fig. 13; Pl. i, fig. 3, right).

The "V" represents a target of the shape of that of a Harris trap, which shape is undoubtedly excellent, but the flies do not enter the V as they do in the latter trap. It may be completely closed, or completely open on the top, or completely open on the top and at the ends. The sides are simply two screens which are hinged or otherwise joined at the bottom and lean outwards away from each other like a pair of slanting "JS" traps; or the trap may fold like a Harris trap—from the ends. Along the outside of the top of each side is slung a long catching-cage, or two, end to end, with the gauze guard of the "JS" trap, the dark strip already described preferably underlying this guard—on the hessian. This trap has caught *swynnertoni* moderately and *pallidipes* well; it about equalled a Harris trap for these combined on two 9-day trials (p. 77). The best day's catch of the JS in this site was 99, of which 91 were *pallidipes*; the Harris's best catch was 97, of which 93 were *pallidipes*. On seven days the dark strip (see above), on one side only, was tested against no strip on the other side of the trap; it caught 235 flies against 104 by the "no strip." The trap is probably capable of further improvement. Jackson found it useful to make it of light grey blanket. While it has regularly caught *swynnertoni* much better than the Harris trap, in single trials against each (in hessian) it caught *morsitans* less well than the SY trap or the SV trap.

The following traps were developed by the writer:—

4. The Single-Screen Awning Trap ("SS": Diagram 1; Diag. 3, fig. 4; Pl. i, fig. 4; Pl. ii, fig. 1).

This is simply a PS trap with an awning (which may be quite narrow) projecting from the base of each side of the catching cage. By means of adjustable awnings designed by Mr. G. Rosch, these can be tested at various angles, or the same trap can be used against different flies or in different conditions. It was supposed also that with awnings strongly dependent it might catch yet more females, but this has not been proved. With awnings projecting at a very slight drooping angle it has made excellent catches both of *pallidipes* and *palpalis*, and comparative experiment has suggested that with horizontal awnings it would have done equally well.

Our first SS traps (SSB) had wooden buttocks or ends (Diagram 3, fig. 7), to strengthen the structure before we used iron, to keep the flies from emerging at the ends on nearing the top of the screen and especially for greater conspicuousness. A comparative experiment suggested that the buttocks might well be discarded. This

was done and the new traps (Diagram 1 ; Pl. i, fig. 4) caught excellently. The writer has had more SSB's made lately, however, for the purposes of a fuller comparative experiment. The forms of these new buttock-traps are shown in Pl. ii, fig. 1. An SSB with horizontal awnings is catching *pallidipes* well.

The SS against *pallidipes*. The following tables give the results of two 9-day comparative trials between three different traps of the same length and depth, hung end to end a yard or two apart (cf. Pl. i, fig. 3) :—

Average per diem :—

First comparative trial (in feeding-ground No. 1, 2nd noon—11th noon, September 1931).

	<i>G. pallidipes</i>	<i>G. swynnertoni</i>	♀ % <i>pallidipes</i>
Harris*	9.88	1.33	69.66
JV	6.58	3.20	67.85
Harris and JV combined ...	13.68 16.46	4.23 4.53	68.96
SS	16.26	0.93	71.13
SY	15.24	7.22	76.08

In this trial the JV catching-cages were mounted on the shoulders of the Harris trap. Each doubtless stole from the other, so they are shown combined as well as separately.

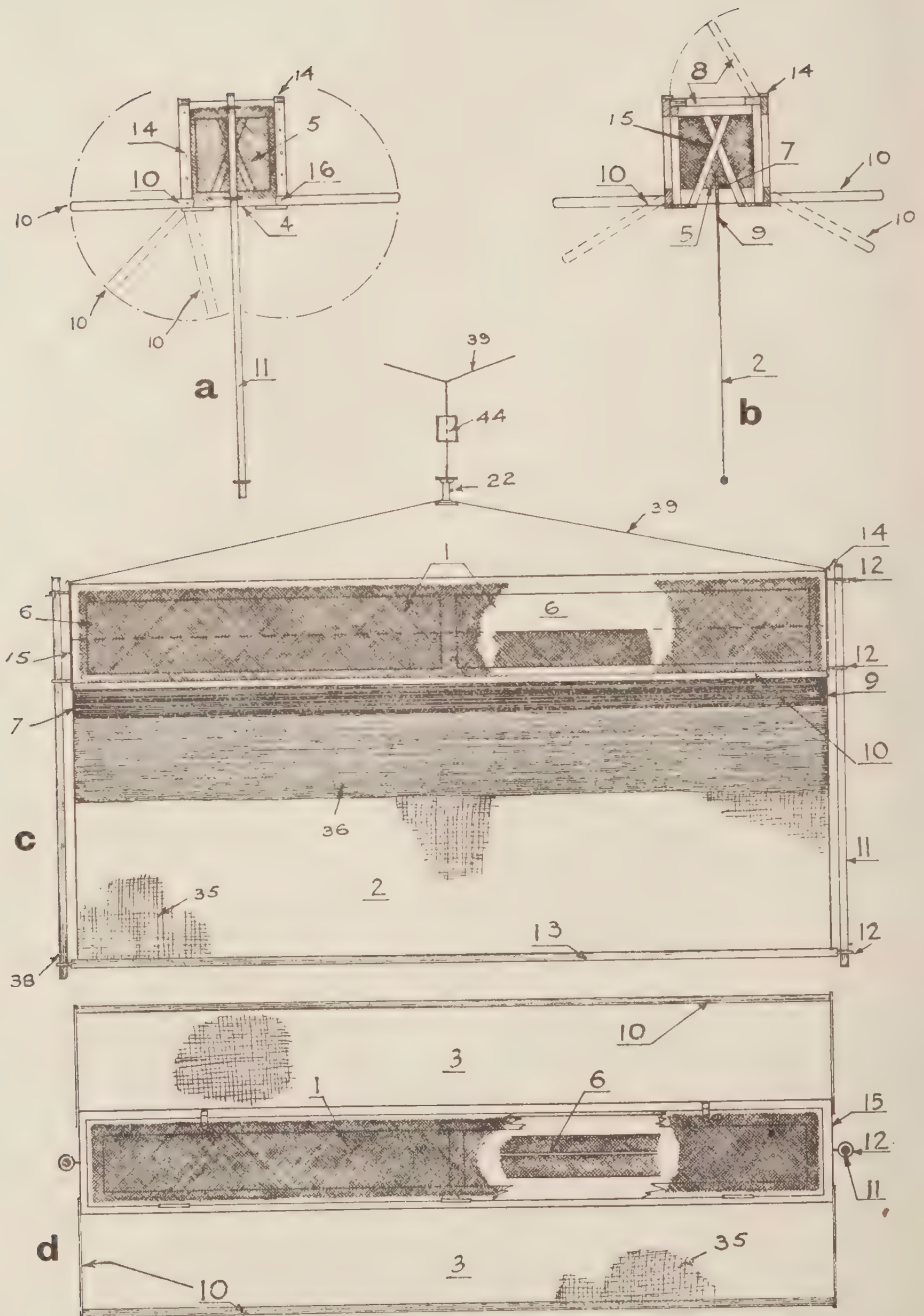
Second trial (in feeding-ground No. 2, 15th–23rd September 1931).

	<i>G. pallidipes</i> (Average daily total)	<i>G. swynnertoni</i> (Average daily total)	Average daily total both species	♀ % <i>pallidipes</i>
Harris	39.62 (41.00 approx.)	0.37	41.00	58.67
JV	32.37 (38.82)	3.75	43.00	76.06
SS	49.28 (50.98 approx.)	2.71	54.00	76.52

In this experiment the Harris and the JV traps were separate (Pl. i, fig. 3). The detailed figures for all traps were lost for 16th September, and for the SS for the 19th, so that the unbracketed figures of the first two columns and the female percentages are based on eight days and, for the SS, seven days. Fortunately the totals have been preserved (and the fourth column, above, is based on them), as has the fact that on every day in this experiment *swynnertoni* was caught in negligible quantities. If we should assume, then, that the same proportion of the latter species was caught on the missing days as on the rest the average total catches per diem of *pallidipes* would be as shown in the brackets. The SY trap was not used.

On the evening of the 23rd, the SS trap had scored 486 flies as against the 387 of the Jackson trap and the 369 of the Harris, nearly all the flies in each case being *pallidipes*. For some unknown reason the Harris seemed unusually low in its female percentage, the other two being well up.

* Mr. Harris kindly gave me permission to use one or two of his traps experimentally.



G. saynneri was present (to man) in quite large numbers and hungry, so that a comparison of the numbers caught shows further what a particularly excellent "trap fly" *pallidipes* is. A few of the 4-ft. SS traps out now are giving quite high figures, but it is obvious from the figures given above, and from figures both from the present traps and from a Harris trap that was used in experiments against *G. saynneri*, that *pallidipes* (of which we had seen very few till we used the traps) is much less abundant in our part of Shinyanga than it was in the Umtolozi Reserve in Zululand when Mr. Harris began to catch.

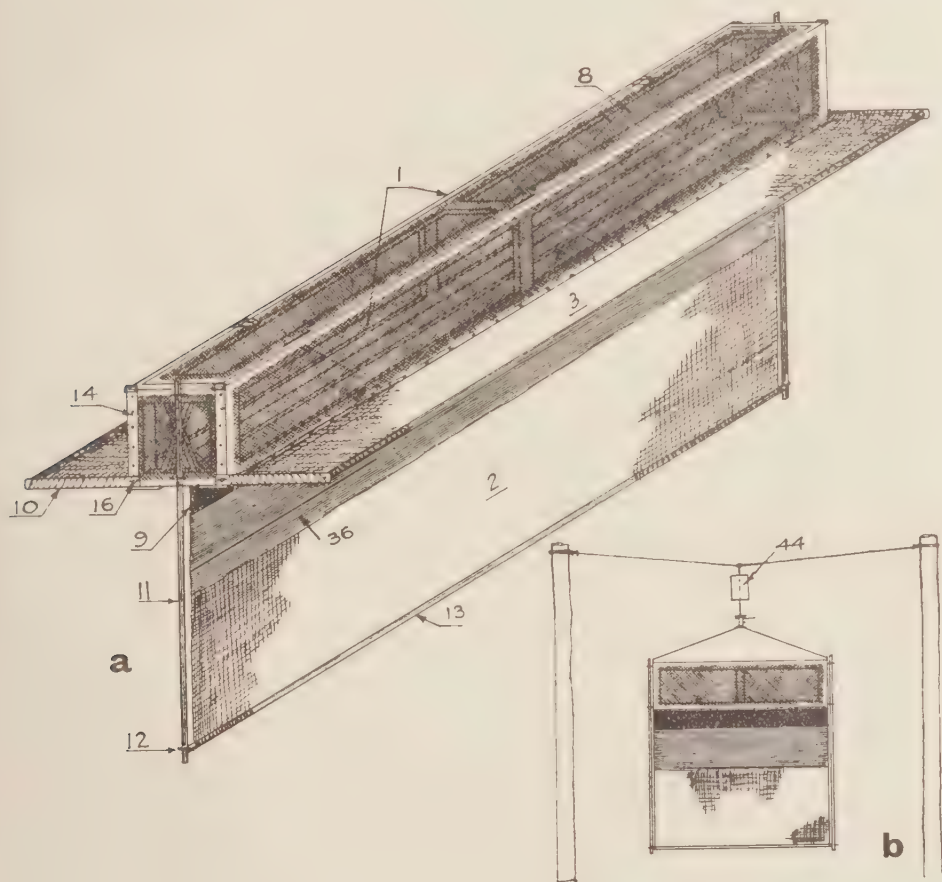


Diagram 2. *a*, isometric view of single screen trap; *b*, plain screen trap suspended between two poles.

It is believed that we have in the SS a trap which, for our *pallidipes* at any rate, is as good as the Harris. Additionally, it folds for transportation into a parcel little larger than the cage or container itself, and the cost of the 4-ft. model, made by native carpenters, is approximately 12s. 6d.—calculating material on coast prices or using local wood.

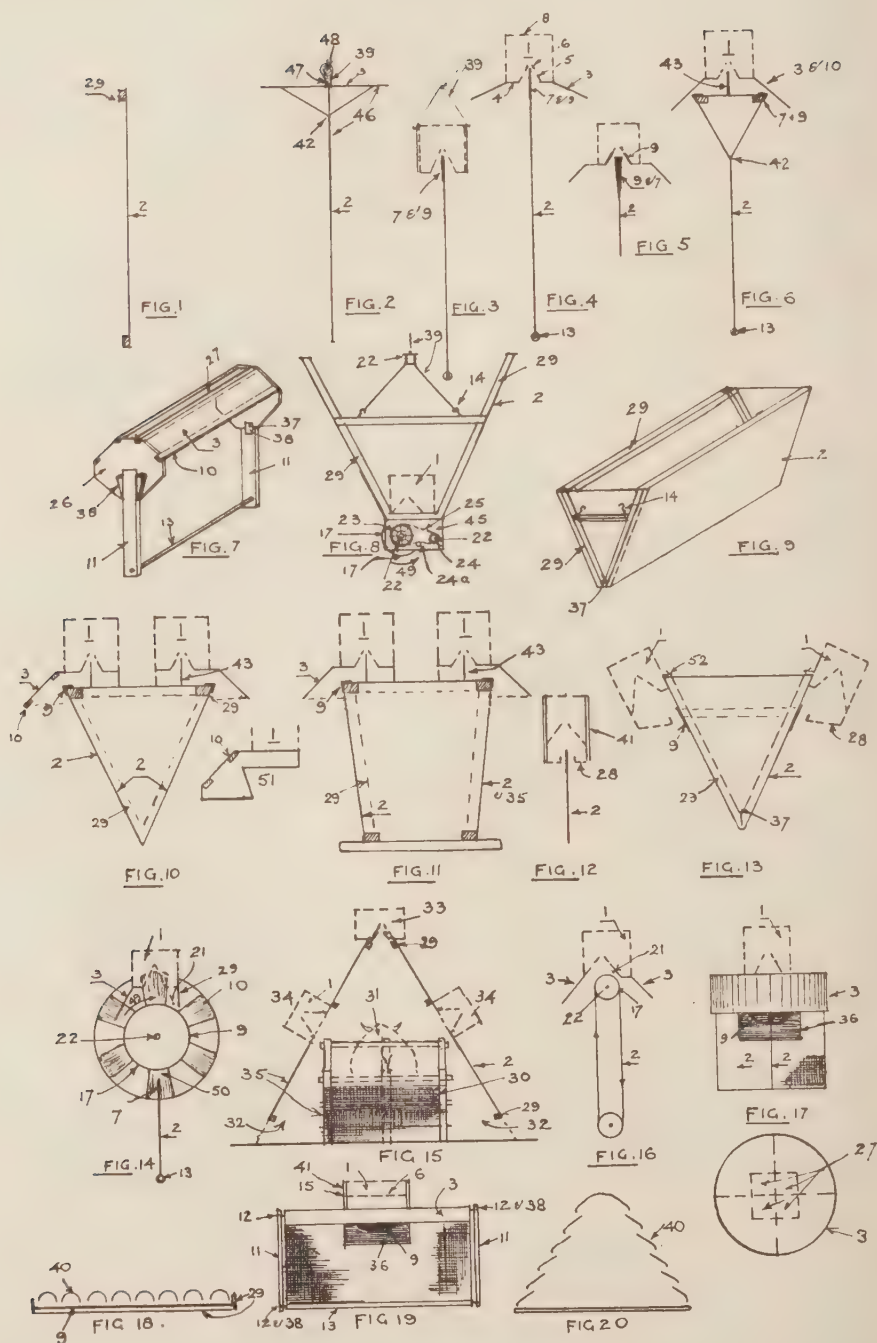


Diagram 3. Details of various traps.

EXPLANATION OF DIAGRAMS 1, 2 AND 3.

Fig. 1, Cross section of the original catching-screen ; 2, ditto of T-Screen ; 3, ditto of PS (plain screen) trap ; 4, ditto of SS (single-screen awning) trap ; 5, ditto of Sy trap ; 6, ditto of SY trap ; 7, isometric view of the original wooden SSB (" buttock ") trap, ends made from petrol-box sides ; 8, end elevation of the SVR trap ; 9, isometric view of the target of the JV, SV and (except along bottom) SVR traps. Thickness of wood rather exaggerated ; 10, cross section of SV trap ; 11, ditto of SU trap (to contain an animal) ; 12, ditto of JS (Jackson's single-screen) trap ; 13, ditto of JV (Jackson's V) trap, catching cage shown unnecessarily large ; 14, cross section of roller screen trap (SR) with fan shown behind ; 15, DLA animal trap. The pen shown too wide, came above the height of the calf and mosquito netting was swathed over the top ; 16, cross section of BSR or Bax's " moving stair-case " trap, with the screen climbing round two rollers, one of which is supplied with a fan ; 17, elevation or cross section and plan of the compartment trap (SCi) ; 18 and 20, rough plans of two forms of the Moggridge trap ; 19, a concentrative screen trap.

In the various diagrams 1 is the catching-cage or container, which may be covered completely with wire gauze or (Diagram 3, figs. 3 and 12) have wooden or otherwise opaque sides ; 2 is the screen, single, or (figs. 8, 9, 10, 11, 13 and 16 of Diagram 3) double with space between ; 3 is the awnings ; 4 is the bottom of the container, from which rises 5 the non-return passage of convergent wire-gauze strips that form the entrance to the catching cage, and 6 is the non-return aperture at or along their meeting-point through which the fly passes in ; 8 is the top of the catching-cage, having a hinged or movable lid to it, which lid need not occupy the whole top or may be in the side or end ; 7 is a board along the top of the screen to stiffen it ; 9 is an attractant of black or dark cloth coinciding more or less with this board, or, it may be, covering the roller 17 : below it or round it (Diagram 1 ; Diagram 3, figs. 17 and 19) may be cloth (36) of some shade of grey, blue, brown or any colour that may be found to be the most suitable ; 10 represents the supports to the awnings, whether attached to their sides, ends or both and whether of iron or wood ; 11 shows two legs, which, passing down, serve as vertical stretchers to keep the screen stiff : they may be of any of several types (*e g.*, Diagram 1, or Diagram 3, fig. 7) ; 12 is the rings screwed in a vertical line into the catching-cage, and the ends of the horizontal stretcher at the bottom 13 (respectively) through which the legs pass ; some alternative methods (37 hinge, and 38 slot) of fastening the legs are shown in fig. 7 (in which the latter are shown too thick) ; 14 represents the screws, rings or hooks for hanging the trap ; 16 is a hinge, bolt or screw at the junction of the supports of the awning and the lower corners of the container that enables these supports to be adjusted at will as to angle in the adjustable forms of trap : rigid supports for the awning, on the contrary, are shown in Diagram 3, fig. 7 (where they are of wood) and Pl. i, fig. 4, where they are iron slats ; 17 is the revolving roller or cylinder of the various roller traps, 18 is the wind-driven fan or propeller which makes it revolve ; the tail-vane that keeps the fan facing the wind is shown in Pl. ii, fig. 2 ; 20 is the brush to disturb the flies on the roller and make them fly up into the catching-cage ; 21 is the trip-wire, just off the roller, which yet better dislodges the flies, though the " brush " or a board should still hang nearly to the roller to block the way out on that side ; 22 represents ball-bearings (usefully provided by old bicycle hubs) ; 23, in the form of gearing we are using at present, represents the large sprocket fastened on to the spindle of the roller ; 24 the small sprocket attached to the spindle of the fan, and 25 the chain that connects them, while 45 is the block of wood, transferable from trap to trap, on which the whole gearing is mounted ; 26 is the buttocks at the end of the SSB trap (Pl. ii, fig. 1) ; 27 represents the openings into the catching cage in the SSB and SC traps (Diagram 3, figs. 7, 17) ; 28 is the gauze guard of the Jackson traps (figs. 12 and 13)—they and the catching-cages are shown unnecessarily large in fig. 13 ; 29 represents the wooden frame of a hand-catching screen and some other traps respectively ; 30 is the calf pen inside the DLA trap ; 31 is the calf, which, however, did not project above the pen, the top of which was closed with ordinary mosquito netting ; 32 is the opening by which the flies enter the DLA trap ; 33 and 34 show alternative positions for catching-cages in the same trap—34 was actually used ; Hessian is indicated by 35 or coarse cross-hatching, grey cloth or its equivalent by 36 or horizontal hatching, hinges by 37, alternative methods of fastening the legs of the trap under 38, suspensory wire by 39, wire gauze in the Moggridge traps by 40 and petrol box (or wooden) catching-cages by 41 ; at 42 in Diagram 3, figs. 2 and 6 or lower, the cloth forming the screen is drawn in—making in fig. 2 an angle that is not too sharp for the entry of the catching-net ; 43 is an extra board guide, with dark cloth covering, which, however, has not yet been proved to be necessary, and 44 is a tin of bird-lime to deter ants ; 46 (in our present " T " hand-catching screens) is a frame of rod-iron, about $\frac{5}{16}$ inch, 47 the point at which the oblong dependant frame rivets (movably) on to the " T " or awning frame (also oblong) above it, and 48 the bamboo or other stick carried on the shoulders of boys from which the screen is suspended ; 49 represents the direction in which a drum turns ; 50 is a space between drum and screen to allow flies to pass, 51 the wooden ends of the catching-cages in the SV and SU traps, 52 the screws, rings or hooks for suspending the JV catching-cages from the " shoulders " of its screens.

The SS against *G. palpalis*. A 6ft. SS, with awnings barely below the horizontal and without buttocks, was tried in May for 3½ days against a 6ft. Harris trap on the Kuja River in South Kavirondo. Again the traps were end to end, two yards from each other, and each was equally conspicuous on a high spit projecting into the flooded river.

The results were as follows :—

				SS Trap (Awnings slightly below horizontal)	Harris Trap.
17th May	...	...	...	30 <i>palpalis</i>	3 <i>palpalis</i> and 1 ♀ <i>brevipalpis</i>
18th "	...	...	...	54 "	7 "
19th-20th May	...	...	...	78 "	4 "
Total	...	...	...	♀♀ 118	♀♀ 12

On the first day the SS trap revolved in the horizontal plane ; on the second day both traps were stationary ; on the last day the Harris trap was fitted with wind-scoops and made to revolve, the SS remaining stationary. Also, on the third day a dark guide-line was provided round the edge of the opening of the Harris trap, which, with these additions to it, has been catching *palpalis* well, I am told, in Uganda ; but it would seem possible from the above-quoted experiment that the SS trap might have done even better. The experiments on the Kuja have been continued by Mr. Symes on carefully controlled lines, and he writes to me two and a half months after their initiation that the screen traps still keep up their very strong lead.

G. morsitans and *swynnertoni*. The SS trap, so promising for *palpalis* and *pallidipes*, is not so good for *swynnertoni*, except with an animal scent, and is apparently less good for *morsitans*.

5. The Y-Screen Awning Trap ("SY" and "Sy" : Diagram 3, figs. 5, 6).

This was another attempt to counter the habit of *swynnertoni* and *morsitans* of flying out of a trap by the way they went in. The top of the screen was widened into the form of a Y, narrow and entering the mouth of the catching-cage (Sy), or wide and remaining below it (SY). The idea was that the fly on turning a top corner of the Y should lose sight of the prospect below and see only the way out by the catching-cage. This device has very considerably improved the catches, but a number of flies still go out by the way they came. It is not, however, so good a trap as the SR trap (see below, p. 83) for *morsitans* or *swynnertoni*. It is also not good for *pallidipes*, except in conjunction with an animal scent, though it normally catches a number. In experiments against *swynnertoni* it has been interesting to note that the SY took this fly in low but appreciable numbers, while the Harris trap hardly took any, seeming to select the *pallidipes* present. A cage for a small animal can be accommodated in the Y of the SY trap, and the Sy is looked on as being the likeliest trap to hold a chemical attractant or a scent distilled from an animal. The SY trap is better with buttocks of gauze or opaque material.

6. The "SV" Trap (Diagram 3, fig. 10).

This resembles the JV trap in shape, and differs from the Harris, as does the JV, in the fact that the flies do not pass through the target but climb up outside it to catching-cages placed on its shoulders. There is no guard, as in the JV, but from the bottom of the outer side of each catching-cage projects an awning which may be quite

narrow. The target is simply two screens hinged at the bottom. The trap is good, but owing to the extra expense of the two catching-cages, it has not been used much, pending the knowledge that the SS trap is probably fully as useful.

In a trial of the SV trap against the Harris trap on one day only, near Kilosa, the former caught 6 *pallidipes* and 25 *morsitans*, the Harris trap nil. The SV beat also the JV trap in a short trial against *morsitans* at Kazikazi. Against *swynnertonii* the same trap, on the second of two days on which it was tried against a Harris, took 26 *swynnertonii* (7♂, 19♀); on the previous day 16; but no *pallidipes*. The Harris in the same total time, five yards away, took two flies only, a ♂ and ♀ *pallidipes*. The figures and periods given are over-small but the relative catches are typical.

7. Cylindrical Screen Traps.

Three different forms have been tried, and the first at least has caught sufficiently well to be worthy of further experiment.

This first form (the Compartment Trap, SCi, Diagram 3, fig. 17) consists of a round board, pierced with a large opening in the centre to admit the flies upward. It can be, say, two feet in diameter, and from its edges there hangs an awning, say, 8 inches deep. Inside this, from the wood and crossing the opening, hangs, in one form, a screen with the usual cloth and colour attractants, in the second, two screens that form a cross with each other. The round piece of wood can be dispensed with by hanging the awning direct from the cage in the form of a shoulder, a ring of the full diameter expanding it below.

A trap of this kind, in which the inside of the awning and top of the screens were lined with dark blanket, took on the Kuja River a burst of 14 *palpalis* in a very few minutes when standing on the ground waiting to be slung. It had only increased this catch to 31 the day after (21 ♀♀, 10 ♂♂). Slung in a small hippo feeding-ground on Maboko Island on 23rd May in quite thick fly and with the ground to itself, it took approximately 60 flies in an hour. On the rest of this day and the 24th it took 63 flies in competition with a Midget SS trap, which took 64, and a 6 ft. SS trap, which took 267 in the time. In trials against *morsitans* and *swynnertonii* it has caught almost nothing.

The second form (basin trap, SCii) is simply a large inverted tin basin, blackened inside, from which hangs (a) a screen, or (b), vertically, a drum covered with hessian, graded through a grey strip of cloth to black cloth or blanket at the top. The trap is suspended from a bicycle hub (Mr. C. W. Chorley's idea) and spins in the wind. This, in Ankole, in quite unsuitable weather, caught *morsitans* better than its competitors, but the total was only 10. It caught 19 *palpalis* in a day when set on the Kuja River, against 3 *palpalis* in the same time and place by a Harris trap. The flies ascend outside the cylinder.

The third is a black umbrella with holes in the centre of the top. A small catching-cage covers these and a screen hangs from the cross-ribs. The whole is slung from a wire. This, in a trial against *palpalis*, caught less well than the others (3 only against 78 in the SS). The outside of the umbrella was covered with hessian except for a black edging.

8. The Roller Screen Traps (SR. I and II, SVR and BSR: Diagram 3, figs. 14 (SRi) and 16 (BSR); Pl. ii, fig. 2 (SRii); Pl. iii, figs. 1 (SRi), 2 (BSR)).

In the SRi the widening, of triangular section, that takes place at the top of the screen of an SY trap becomes a cylindrical roller, lying horizontally, which is made to revolve by a wind-driven fan at one end. This roller is covered with cloth and, as the tsetse-flies land on it, carries them up and round into the opening of the catching-cage till they meet a "brush" of hair, felt, board or other material that hangs from the cage and lies against or almost against the roller beyond the far side of the opening. Disturbed by the "brush" they fly into the cage. A "trip" wire, just not touching

the roller but lying along it, is proving even better, as it does not act as a brake, but a board only just not touching the roller is equally good. The lower part of the screen is single and hangs below the roller. It is separated from the latter by a space ($1\frac{1}{2}$ inches is useful) through which flies settling on the wrong side of the roller are successfully carried past the screen. With the roller large enough this lower screen becomes unnecessary (the SRii trap: Pl. ii, fig. 2). At the end of the trap away from the fan is a vertical tail-vane which keeps the head of the trap directed to the wind and the fan thereby running. The latter should be capable of starting in the lightest of gentle breezes yet should at no time run fast.

Fast revolution of the drum causes the tsetse to fail to land on it, or, if they land, to baulk on the threshold of the catching-cage. Trial is at present being made by Mr. Rosch of various "governing" devices. Of these a large bicycle sprocket combined with a very small wheel with similar cogs, specially made, ratio 1 : 5, the two wheels connected by a shortened bicycle chain, has so far proved the most successful. It starts very lightly indeed, and except in a very strong wind the drum revolves slowly enough, though a ratio of 1 : 10 would be better. The gears of old Government bicycles should be easy to collect without expense. A small awning projects above the entrance in the position of the awning of an SS trap. It is found, in the SRii particularly, to serve better than the dependant tin or gauze guard that was first used to prevent the flies from flying out again; without it they regularly flew out. It projects slightly downwards and (in our big-diameter model) passes three inches away from the nearest point on the drum. When it was nearer than this the flies baulked on reaching it; when it was further they flew out from inside. It was an extraordinary thing that they baulked at this point at anything close, even wire gauze directed towards them, yet on reaching the "brush" they would let this actually stroke them if it were of light material and lay loosely. A mere guard at this point did not disturb them at all; the "trip" wire or board must actually jar them.

The trap was suggested to the writer by watching the numbers of flies that sometimes collect on the black strip of an SS trap and do not quickly go further.

In the BSR (Bax Roller-Screen Trap: Diagram 3, fig. 16; Pl. iii, fig. 2), suggested by Mr. S. Napier-Bax when watching the construction of the writer's first SR trap, there are two rollers, one at the top of the screen, the other at the bottom, and the whole screen climbs upward over them like a moving staircase.

SRi, with a small-diameter roller and a screen hanging below it (Pl. iii, fig. 1), takes chiefly the hungry flies. Those that are not hungry are mostly left out, as they disport themselves on the screen generally and come little to the dark drum (or, in the SS, dark strip) at the top. A larger drum (Pl. ii, fig. 2) takes all comers. At the same time an SR with a screen, though running much too fast to be catching for more than a tithe of its time, caught far more *swynnertoni* than SS and SY traps tried against it.

BSR, as tried against *swynnertoni* and *morsitans*, also seems to take most of the non-hungry flies as well as the hungry. It is true that the former are almost entirely males, as the really non-hungry females of these two species do not appear to any trap, unless, perhaps, it should have an attractive scent.

To obtain the maximum of conspicuousness for these very promising traps, screens on a light wooden framework and slanting up and out at an angle from the supports of the drum have been tried on a SR trap with a large drum (SRii: Pl. ii, fig. 2), and have appeared effective. This has led to a variation of the trap (SVR: Diagram 3, fig. 8) which takes the form of the large V-screens of a JV or SV trap with a small-diameter (e.g., 6-inch) roller running the length of the "belly" and surmounted immediately by a catching cage that also lies in the angle between the screens. There are no ends or top connecting the screens, for the wind must blow through to the tail-vane and orient it. As the whole trap is hung from a bicycle hub its movements in a fair wind, swinging sharply to meet variations in the latter and sometimes veritably prancing, are like those of a restive horse and greatly add to its conspicuousness.

The colour-attractants have followed the roller to the belly. So far, *morsitans* has appeared to settle best on the roller in the SRii and SVR when that has been fully lighted, *pallidipes* when it was flanked by the lower lips of the screens and so shaded. It is hoped that we have in the SR (i and ii) and BSR as good traps for *morsitans* and *swynnertoni*, and in the SRii and SVR for *morsitans* as the SS is for *palpalis* and *pallidipes*. The SVR needs more careful adjustment for *morsitans* (to avoid baulking) than it needs for *pallidipes*. Actually the SVR takes *pallidipes* in some numbers even with the roller stationary.

9. The SVB Trap.

Consisting of the usual open V of two screens slightly separated below and with a catching-cage running the length of its belly just inside the screens. This, tried in the form of the SVR trap with its drum removed, was not successful in a preliminary canter :—

	<i>pallidipes</i>			<i>swynnertoni</i>		
	♂	♀	Total	♂	♀	Total
6th September. SVR trap, wind light to moderate sometimes strong	15	116	131	16	3	19
7th September. SVR with drum removed (SVB)	4	7	11	1	0	1

G. swynnertoni was negligible, being nearly all males. With the drum in but the fan off the total catch ran on two days into the thirties, suggesting that the SVB with a narrower opening is better than with a wide one, though by no means equal to the SVR.

10. Concentrative Screen Traps (Diagram 3, fig. 19).

The catching-cage is what costs the most in our screen traps. We are therefore experimenting in placing a small catching-cage (1-2 ft. long) on the top of a full-sized screen, trusting to bring the flies in by concentrating our attractions on the area of screen immediately underlying the catching-cage. It amounts to a scheme of directive marking analogous to that found in flowers. The experiments have not gone far enough to be worth recording in detail. The flies are duly taken and in some numbers, but whether as many as a full-length cage would take in that site has yet to be tested.

The principle, if successful, might be applied to the "roller" traps as well as the SS and similar traps and, by shortening the roller, enable the trap to be run if desired by another agency than wind. This might be clock-work combined with a powerful spring as in the Japanese house-fly trap.

11. The "Moggridge" Trap (Diagram 3, figs. 18, 20).

In this trap, invented by Mr. J. Y. Moggridge, Field Experiment Officer, the screen consists of a shallow box vertically placed, the inside of the back of which is covered with black felt. Lengths of wire-gauze with spaces of less than their width between them cover the front of it, vertically also, curved outwardly like slices cut from the pipes of an organ. They lead into a catching-cage above or behind. As in the case of the roller traps, the object is to catch the numberless unhungry *morsitans* and *swynnertoni* that come to but do not enter the ordinary sight-trap, and the idea is that the flies may be attracted by the black spaces between the "pipes," go to these, and, trying to fly out again, be more likely to strike the concave, inner side of a "pipe," these being wider than the spaces, and buzz up it into the opening. It was thought that a form of this trap would be specially useful for the backs of lorries.

The flies definitely tend to fly up thus when in, but few, so far, have gone in past the "pipes" in the first place. The trap is probably capable of improvement; it would possibly be better to make it project in triangular form, each organ pipe so covering the next that the fly is led on from one to the other until, at the apex of the triangle, it finally reaches the catching-cage (Diagram 3, fig. 20). The trap may be relatively expensive, however, as the result of the amount of gauze used.

G. The Electric Screen (SE ; Diagram 4 ; Pl. ii, fig. 3).

The trains of the Territory, passing through the fly-belts, carry flies in great numbers and spread them into new areas. The present appearance of occasional *morsitans* in Shinyanga and the creation of the Hika fly-belt in Manyoni-Singida both seem traceable to this source. The flies travel mainly on the brake van and come forward along the train when it slows up. Doubtless many also come direct to the carriages.

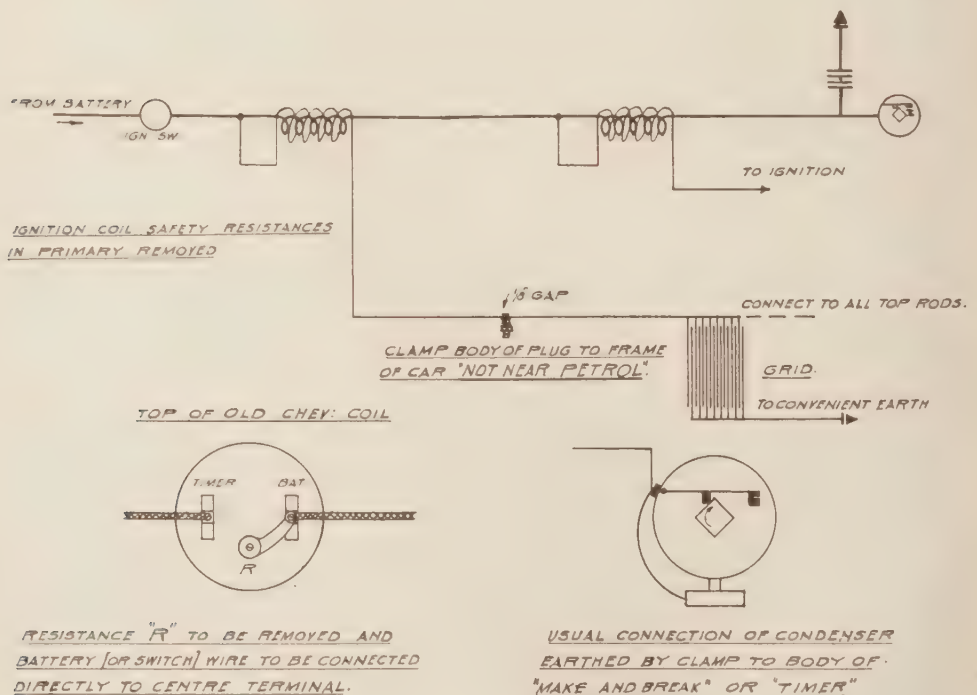


Diagram 4. Scheme of the Electric Trap.

In October His Excellency the Governor expressed the wish that the trains should be supplied with tsetse traps. The writer thereupon suggested the trial of an electrified screen on the back of the brake-van. He was placed in touch with Mr. H. Manson, Electrical Engineer to the Railways, and a number of experiments were carried out with his expert aid. Mr. J. McHardy, Medical Entomologist, very kindly assisted in the earlier of these.

1. Experiments in the Workshop.

Mr. Manson has kindly written the following account of our experiments in his workshop in more technical detail than the writer could give :—

A small box about 10 inches cube was made having one open end : this end was covered by a grid made of parallel 10-cwt. galvanized iron wires. Alternate wires were connected to the poles of the current-supplying apparatus.

Individual tsetse-flies (*morsitans*, *swynnertoni* and a few *pallidipes*) were introduced through a small hole in the side of the box opposite the grid and the effects were noted when the flies made contact with the grid.

The following "currents" were tried :—

(a) 220 V.DC., 500 V.DC., 440 V.DC. The first of these voltages was quite ineffective, the second and third slightly less so, but even here only slightly prolonged contact amounting to 2 or 3 seconds was effective in stunning the flies.

(b) 2,000 V. and 3,000 V. The effect at each of these voltages was instantaneous, the flies falling immediately on contact with the grid. The effects on different individuals varied considerably, however. Some were completely stunned and others "buzzed" on their backs for varying periods in attempts to fly. Most of these were able to fly 3 or 4 minutes after contact and a small proportion flew in from 5 to 10 seconds after contact. The widely divergent results with different individuals was doubtless due to the type of contact made with the grid. Leg (and to an even greater degree wing) contact appeared to minimize the "stunning" dose. Duration of contact was also an important factor, long contact at voltages down to 300 appearing to stun. Stunned individuals together with untreated "controls" were kept, but the results were inconclusive. A large proportion of the "electrocuted" flies recovered in a few hours or less and appeared quite healthy. House-flies were killed more easily.

3,000 represents about the highest voltage which can be practically applied, the spacing of the grids being necessarily limited to the distance over which a fly can make contact with a pair of wires on the grid.

Higher voltages up to about 6,000 were in fact tried, but with these the principle was varied somewhat, the grid distance being so proportioned as to be just above sparking distance. The fly in flying through the grid (fine wires were used) made a low resistance path and thus became part of the circuit. The effects were satisfactory but practical difficulties in designing a suitably insulated grid sufficiently rugged to withstand rough handling and weather made this line of experiment doubtful.

The source of supply in the high voltage experiments was an induction coil. Throughout these experiments currents were not measured, implements capable of indicating "instantaneous" values not being available.

2. Experiments in the Field.

A grid was made, of Mr. Manson's designing, 5 ft. long and $1\frac{1}{2}$ ft. deep of $\frac{3}{8}$ inch oxidised iron rods having a spacing of one-eighth of an inch. This was backed by a screen of black felt and was so fixed as to cover the tail-board of an Albion lorry. Below it was attached a zinc tray to catch the flies. This last had a little oil in it—Mr. McHardy's suggestion.

The contrivance was tried in fly country (*morsitans*, *pallidipes* and *brevipalpis*) in the Utete fly-belts with very encouraging results. On the outward trip many of the flies failed to arrive in the tray which may have been too narrow for driving into a wind. On the return journey about as many flies were killed by the oil as were caught by a fly-boy control off the back of the "cab" of the lorry. On a second day's trial the party preceded the lorry in a car and halted continually to catch all flies possible for the later workshop experiments. The lorry coming behind was thus at a great disadvantage, yet caught nearly as many with its trap. These results were distinctly encouraging. The current in this experiment was supplied by a high tension ignition magneto from which the contact breaker had been removed. The belt was driven from the lorry engine. The voltage varied from 1,000 to 2,000 (peak), the maximum frequency being 30 cycles.

In November Mr. Manson tried the same grid on the back of a train through fly country between Tabora and Kigoma. The grid was mounted on the rear vehicle of the train and was supplied by a magneto driven at constant speed by an electric motor; voltage 1,500 (peak), frequency 20 cycles. Flies were rather scarce on this journey but, standing on a buffer and watching, Mr. Manson noted that none that touched escaped. He regarded the experiment as an unqualified success.

The exact practicability of the electric trap, as regards easy attachment to and removal from lorries travelling on infested roads, whether the proportion of the flies killed coming to the rear of trains will be worth while, etc., remains doubtful.

It had been thought that this trap might be useful not only for cars, motor-bicycles and trains but for boats with outboard motors which might cruise close round islands or up and down rivers, drawing the flies out. Submerged rocks would be an obstacle to this in the Lakes and in any case *palpalis* is coming so well to our SS traps set on land that this addition to our armoury is probably unnecessary. The supply of power to sets of electric traps, in feeding-grounds, by means of a wind-mill, or, when available, water, has been thought of, progressive movement on wires being perhaps at the same time imparted. These would be highly expensive compared with our other traps and would need more attention.

H.—“Animal” Screen Traps.

1. The “SU” Trap (Diagram 3, fig. 11; Pl. iii, fig. 3).

This is a screen trap widened to accommodate a large animal. A small animal can be accommodated in a cage in the Y of the SY trap with some gauze for ventilation. For a large animal the two screens of the SV trap are merely pushed apart at the bottom, the frame-work is greatly strengthened and lined with wire-netting to prevent damage by the animal to the fabric, the outside is covered with fabric (hessian or other) except for strips of wire gauze for ventilation, and there is a door at the end through which the animal enters and, when the experiment is finished, backs out again. The animal is protected from the flies. A narrow awning suffices, though a wide one may be used.

In the experiments hitherto a calf has been used as bait. In the first few experiments the DLA tent-like form described under I (below) was used for its housing, with catching-cages in its sides. To protect the calf better and bring the trap into line with the general “screen” design the SU was substituted for the tent and continued to catch as well as the DLA trap was doing at the time of substitution.

A control trap has been used in every experiment, exactly similar in appearance and size to the animal trap in use, but not containing a calf.

To take both traps together (DLA and SU), six experiments lasting only from two to six and half hours each were carried out between 16th September and 3rd October and one on 10th October with a calf in one trap. Results: calf, 1,156 flies; control 472. The largest catch was 584 flies caught in the calf trap in $5\frac{1}{4}$ hours against 244 in the control, which, on this occasion, was only 4 yards away and certainly shared in the scent.

Nine similar experiments were carried out between the same dates with no calf in the calf trap and the experiment running all day. Results: calf trap, 201 flies; control, 214.

A trap containing an invisible calf has each time been the scene of greater animation on the part of the flies than any trap not containing an animal. The question of “scent” thus raised is discussed in Section L.

2. *The Carried Umbrella.*

Mr. C. B. Symes, Medical Entomologist, Kenya, and the writer, tested the effect of attaching a small gauze catching-cage to the top of a two-shilling umbrella, which was then carried about by a native who acted as bait; 35 flies (*palpalis*) were caught in a period not timed. This was a much lower number than would have been caught by a good boy in the time with a net, but the idea may be worth developing in relation to the raw native who, dwelling in an area we are attacking, buys or would like an umbrella.

I. *Traps in which the Flies are Attracted or Conducted from Light into Relative Darkness and Darkness to Light.*

Two of our traps have come into this category—one of our animal-traps, still a potential part of our armoury, and two further forms of our roller trap.

1. *The DLA Animal-trap* (Diagram 3, fig. 15; Pl. ii, fig. 4).

This differed from the Harris trap structurally in not being suspended and in not possessing a platform. Its framework stood on the ground and took the form of a four-sided tent, but a bell-tent form would be equally useful. The catching-cages were suspended outside, one on each long side of the tent, but, in the bell-tent form especially, could be on the top, when it would much resemble a crinoline trap for mosquitos. It differs from this trap, however, and the Harris, in a very fundamental point, namely, the presence of an animal inside it. The smell of the animal (presumably, for the animal itself from outside has been invisible—not that it need be in practice) attracts the flies into the chamber, whence later, on wishing to emerge, they fly to the light. It is a particularly excellent trap—at any rate for *pallidipes*.

2. *Dark to Light Roller-traps* ("DLR").

The Harris patent has pre-occupied the four-sided "dark to light" form in relation to the fly that enters therein of its own accord. It has left that form open to the roller-trap, which, turning its roller by means of the wind or otherwise, conducts the more obstinate species in willy-nilly.

In this case, instead of conducting the fly from light outside to light in the catching-cage, as, broadly, happens in our screen traps, it carries it from light into the relative darkness of the four-sided chamber. Arrived therein on the roller the insect flies to the bright opening above, whether of its own accord on entering darkness or brushed off or disturbed as described on page 83. It is doubtful if this darkness to light roller trap (so far being made as an experimental trap only) will catch more than the screen-roller traps (SR, SVR and BSR). It is also more expensive than either these or the Harris trap and it will take a larger vane than the former to keep it head-on to the wind, but it is a form that seems worth trial. Even its one-roller form, with the roller in the opening in the belly of the trap, or in the side of the belly, and worked by wind or machinery, differs from the Japanese drum-trap in important details. The "two-roller" form (suggested by Bax) in which the whole or part of the side of the trap climbs up and down round the rollers, is particularly different.

Both differ completely from the Harris trap in the principle on which the flies are led in, despite the unavoidable resemblance in target construction and appearance, which is obviated, however, by giving the trap the bows of a boat at each end to keep it head-on to the wind.

J. *Traps for Attachment to Vehicles.*

The promising electric trap has been described. Traps of the SS and SY types have been attached to the backs of a Chevrolet lorry and a box-bodied Chrysler, the vehicles acting as bait, and have caught large numbers of flies (one SS, for example, well over 300 in a 4-mile run through a fly-belt); but always far larger numbers of flies have stayed outside the traps. An Sy trap attached to a cattle-truck on a train in *morsitans*

country was not successful. The roller-trap (BSR form) would probably be useful on vehicles. One should certainly be able to turn a car or lorry into a highly effective collection of traps, but, as with a train, there is a lot of surface to trap off and our own experiments here have not yet been pushed to completion.

Bird-limed sheets on the back of a vehicle, the subject of the writer's earlier experiments in this direction, were extremely effective.

K. Possible Plain Wire-Gauze Traps for Paths and Gaps in Fly-Barriers (PCM Trap).

It is possible that dense continuous thicket, fenced in, will make a good fly-barrier, and we are experimenting now in its minimum proper width and cheapest production. We also propose to try plain "wall" barriers, though it is difficult to think of a material cheap enough. Mr. C. W. Hobley, commenting on thicket-barriers, has passed on to the writer at the moment of completing this paper a suggestion made about them by Sir Peter Chalmers Mitchell—for which thanks are hereby returned.

Sir Peter experimented with netting and bees. The latter and their hives were in an open enclosure of quarter-inch netting. The netting being invisible to them, the bees did not fly over it but dashed at speed into it, until in the end, they desisted. Mr. Hobley (11.vii.32) passes on the resultant suggestion as follows:—

"For use over long stretches the cost of maintenance would probably rule out the use of netting, but it might be used to reinforce weak stretches of your protective bush belt until they thickened enough by natural growth. Or again it might be of use to protect a native village or a camp for workers in the tsetse campaigns."

The writer had thought of wire-gauze as one possible substance for his vertical barriers against tsetse, but, regarding it as expensive and difficult to protect against game, had thought of it rather as a top to an opaque fence. He had not thought of it as a stopper of gaps in thickets or in connection with the further idea which Sir Peter Chalmers Mitchell's very excellent suggestion has inspired. The tsetse flies low and the writer believes that a high wire-gauze fence might exclude it, were its top turned over. The flies buzz up an invisible barrier but our "Jackson" traps have shown that a small "turn-over" effectively stops them, making them buzz back again. Such a fence, on a long front or protecting gaps, would have to be combined with a particularly strong game fence. The "further idea" is for a trap consisting of a tall transparent catching-cage only, set up on paths much used by the tsetse and flanked with opaque material. It could not, however, compete with a cheap scent trap should such be developed.

L. Scent as a Bait.

Aniseed, valerian and asafoetida have each been briefly tried against *morsitans* as a bait, but so far without success. Urine, dung, blood and hides (fresh and dry) have been equally unsuccessful against *swynnertoni* and *pallidipes*. Oxen just killed and at once motored through *swynnertoni* appeared still attractive. A topi antelope an hour after death did not seem attractive at all. Compare with the case of the oxen the fact that *freshly* shot game animals continue to attract tsetse-fly and that the latter continue to probe eagerly.

The calf experiments described above were most striking in their results, but the explanation is still not fully settled. The calf was invisible from outside the trap. Whether the fly, on detecting a desirable scent, flies upward for a short or long distance and so reaches its quarry, finding it at last by sight, or whether scent is purely a close-range sense and merely incites the flies that reach the trap anyway to greater persistence and effort, so that more get into the catching-cage, is not yet known. Dr. Nash is strongly against the first view, on the strength of his experiment at Kikori (*Bull. Ent. Res.*, xxi, 1930, p. 251), in which blinded flies were not seen again, while flies

deprived of the use of their antennae were recaptured in the same numbers as the untreated controls. Against it also is the fact that the larger proportion of *swynnertoni* and *morsitans* that come to mere sight traps do not go into them. On the other hand, the first view is supported by the facts (a) that the *pallidipes* that come to a trap do seem to go into it, and the captures in the calf-bait experiments were almost entirely *pallidipes* (as against *swynnertoni*, though the latter were seemingly far more abundant outside); (b) that almost all the flies that stay outside the traps are males, while the female percentage in the calf experiments was high (75.02 %, control 77.88 %); (c) that the scent of the animal appears to influence favourably the catch of traps a number of yards away. Thus on the day of the first big calf-catch, the calf-trap and control were in a small opening in the bush, measuring 20 yards only by 27, in which several other traps were situated 25 yards to windward of the calf, except the calf-trap control which was only 4 yards away. All caught heavily, as follows:—

	Totals	
Calf-trap in 5½ hours ...	584 flies	
Control " " ...	244 "	
SS trap in the day ...	97 "	(maximum in this spot on any other day 62)
JS " " " ...	31 "	(" " " " " 8)
Harris trap in the day ...	97 "	(" " " " " 52)
JV " " " ...	58 "	(but previous day took 99).

That the control, so much nearer, should have caught so many more flies than any trap other than the calf-trap, seems significant. As regards the other traps, however, it may have been merely an exceptionally good day. This was suggested by the fact that a small SS trap sixty yards off and only getting the wind occasionally did better than usual also, catching 108 against its other maximum of 48.

Mr. J. Y. Moggridge later found that the SY trap, normally nearly useless for *pallidipes*, caught that fly in large numbers when cattle were working near it, just as the SS trap, normally poor for *swynnertoni*, captured this fly also extensively under the same condition. The flies certainly seemed to misassociate the scent with the trap. They came to it in greater numbers than usual—whether from the oxen visually or, missing the latter, directly, in following up their scent, is unknown, though important. Certainly, having arrived, they must have made greater efforts than usual to enter traps which generally they do not get into.

SY/3, oxen working near:—

				<i>G. pallidipes</i>		<i>G. swynnertoni</i>		Total
				♂♂	♀♀	♂♂	♀♀	
29th October	...	...	...	36	54 (90)	15	34 (49)	139
30th	"	...	...	10	27 (37)	6	15 (21)	58
31st	"	...	...	24	58 (82)	6	19 (25)	107

Previously to the proximity of the oxen the daily catches of this trap were exceedingly low.

Very possibly the explanation which favours close-range attraction is the right one. We can only settle the question by experiment and we hope to settle it soon.

Naturally we cannot sprinkle a large piece of country with calf-traps. Our effort now is to ascertain which of the scents of an animal is the one (if there be only one) that attracts the tsetse and then ask the chemists if they can reproduce it. We shall also test scents empirically. Meantime the animal-traps may be useful in limited areas, such as small islands and riverine strips, for destroying more of the last few flies than sight traps can attract in. They will also be useful for ascertaining the animal preferences of the different species of tsetse-fly.

M. Reasons for the Varying Reaction to Traps of the Different Species of *Glossina*.

Much further investigation is necessary before any definite conclusions can be arrived at on this subject, but it may be stated generally that *pallidipes* will apparently enter traps characterised by shadow more readily than *morsitans*, and the latter than *swynnertoni*; that each of these flies may be induced to enter shadow to a greater extent during times of drought, which in the case of *swynnertoni* has to be more accentuated; that *pallidipes* and *swynnertoni*, at any rate, will more readily enter any reasonable trap, shadow or no shadow, when an attractive scent is pervading its immediate neighbourhood, though this has not been tested for *morsitans*; and fourthly, that weather conditions, which always exercise a strong influence on the behaviour of *morsitans* and *swynnertoni*, have much to say in the question whether and in what numbers either of these flies will enter a particular trap on a particular day or at a particular moment.

The relations of trapping to weather are being studied by ourselves and (in relation to *palpalis*) by Mr. C. W. Chorley in Uganda.

N. The Possibilities of Trapping.

1. Against *Glossina pallidipes*.

This, as shown already, is a specially "trappable" fly; good, visually attracting, hanging traps have been found for it; and that a good trap, even of this type, without scent, may take huge numbers of it where it is sufficiently dense and conditions are suitable, is shown by Mr. Harris's achievements in Zululand. For example, 75 traps there, at the time of the writer's visit, had caught in one month 157,074 flies or an average of 69-80 flies per trap per diem, and the present total catch is something enormous.

On the other hand, only a small proportion of a *pallidipes* population appears to man, and it is not yet certain that all *pallidipes* that see the traps go to them, even if all that go to them should go in.

It has been indicated already that, using a standard-sized Harris trap and an SS trap that was catching *better* than the Harris trap, we were able, by adding scent to one of the writer's animal traps in the form of a calf inside, to catch by means of it many times the number of *pallidipes* that was being caught by either of the traps just mentioned, the maximum catch of the calf-trap (in 5¾ hours) being 560 *pallidipes* and of either of the others, in this whole day, or any day, only 97. In other words, by no means all the *pallidipes* present were being caught by mere "sight" traps, including the Harris.

Mr. Harris's experiments in Zululand followed or coincided with (a) a great destruction of game animals by him in the general area—35,000 in all, the reserve having become over-populated; (b) an exceptional drought. It is true that the more limited area in which the traps were set escaped the more intensive killing, and it is certain that the huge numbers of flies the traps have removed must have affected seriously the fly-population, but it may also prove that either or both of (a) and (b) are needed to raise the continuous catch even of *pallidipes* to numbers the subtraction of which from the fly population will lead to the fly's extinction. With us, it has definitely been the case that the catch of *pallidipes* in traps and of *swynnertoni* at man has fallen vastly during the rains, though there was no question of the fly having been caught out; and, on the other hand, periods of high evaporation have been periods of big rises in the numbers caught.

Further, *pallidipes* occurs under a greater range of conditions than any other tsetse-fly. It inhabits the edges of rain-forests, or even the interior if the undergrowth be sparse or removed; it lives in the East African coast-belt with its prolonged high-humidity periods; it lives in *morsitans* areas of medium rainfall; and it is found

as well in the far drier thorn country of Zululand and Shinyanga. In parts it even overlaps with the semi-desert tsetse, *longipennis*. It is unlikely that it will be equally trappable with sight traps—the same sight traps at any rate—over the whole of this range.

It is felt, nevertheless, that where a sufficient continuance of suitable trapping conditions does exist or can be provided, there is great hope of reducing *pallidipes* to very small numbers by traps in belts that are naturally small or that can be divided. The great slump in catching that took place very locally in Shinyanga when a few traps in a single day had taken 1,200 flies in a "feeding ground" measuring 20 yards by 27 may be noted, perhaps hopefully; but whether additional measures will be needed for finishing it off cannot yet be foreseen, though this seems probable.

Parts of Kenya, combined with Shinyanga and Kilosa in Tanganyika, appear to offer the best opportunities for all-round observation on *pallidipes* and for experimentation in trapping it under a variety of conditions.

2. Against *Glossina morsitans*.

The Harris trap will catch quite fair numbers of *morsitans* under late dry season conditions (the average for a few days was 50 a day and doubtless higher catches would be made under conditions of even greater fly-density). But *morsitans* appears to man far more freely than does *pallidipes*, and it has therefore been possible to say here, from definite and repeated observation, that even when this trap, or one of ours, appears to be catching many flies, far larger numbers are staying outside it. Further, when traps had failed to catch at a small dry swamp near Kilosa in October, the flies being wanted as material for an experiment, a trap was carried round the swamp on the shoulders of natives and a fly-boy caught off it. He caught 35 *morsitans* including 7 females. Having caught 28 males he ceased catching these. Many of the males thus left and many flies coming subsequently were on the trap during its next round, when it was left to catch for itself; but it caught one fly only. This experiment has been repeated less formally dozens of times; a native with a net has always caught far more *morsitans* and far more *swynnertoni* either near or away from the most successful traps than those traps can catch themselves.

We have now traps that appear capable of taking nearly every fly (*morsitans* or other) that comes to them, namely, the "roller" traps. Yet, on first trial, under conditions typical of the wet season and the first half of the dry season, they showed themselves capable of taking numbers of males, but took few females; for the latter, when not needing food, simply do not trouble to appear. At the time of writing, in "hungry" weather, many more females are taken.

It therefore remains to be seen by experiment, first, whether the annual catching period even of these traps (one of them on first trial particularly excellent for *morsitans*) is sufficiently long to be useful if unaided by a local expulsion of the ungulate population to raise the hunger of the females, such a method being both difficult and, if it can be avoided, undesirable; second, whether even this will help much under conditions of low evaporation.

3. Against *Glossina swynnertoni*.

This fly is more refractory than *morsitans* and the remarks made above apply to it also. We have found the Harris trap nearly useless for it. The JV, SU and SY, and even SS traps will catch many of the hungrier flies (though only securing appreciable numbers in very dry weather), and the addition of a calf in an SU trap adds to these numbers; but always a great many more may be seen outside. Even the flies which are hungry have the exasperating habit, mentioned already, when they near the top of an SS screen in particular, of flying back by the way they came. *G. morsitans*

shares this habit. The SR (roller) traps met with the same treatment by both *morsitans* and *swynnertoni*—the flies shied off in passing the bottom corner of the catching-cage or any guard, however thin, that descended from it; but judicious spacing and a re-arrangement of details overcame this, though *swynnertoni* still tends to shy on entering shadow. Generally speaking, these two species will not pass an object standing too close to the screens, which applies even to Jackson's gauze guards. The reaction is possibly that which protects them from the blow of an animal's tail or from twigs brushing its skin. SRV is not a successful catcher of the species, but the other three roller traps, SRi, BSR and SRii (especially) catch it well.

A season's catching with these traps is necessary before we can judge of the prospects of trapping-out *swynnertoni*.

4! Against *Glossina palpalis*.

Here, the writer believes, lies the chief—or the earliest—hope of destroying a tsetse mainly with traps. *G. palpalis*, as the writer has seen, is an exceptionally trappable fly—more so than even *pallidipes*. An important point, to judge from our Kuja River experiment and from that on Maboko Island, to be described below, is that this fly appears to come well to traps even in the wet season and the dry hours of wet days, which the other flies (with us) do not.

Further, the distribution of *G. palpalis* in East Africa is, for the most part, linear and the fly is one that readily uses paths. There should, therefore, be little difficulty in so placing the traps that they must intercept every fly. Starting with the tributaries and clearing all fords to a width that will act as a barrier, the riverside fringing thicket can be broken into narrow strips a few miles in length that would appear to be vastly easier to deal with than the blocks of country we attack in Shinyanga, containing *swynnertoni* and *pallidipes*.

Given the breaking-up of the rivers ahead of the trapping, the latter process, aided by guide-paths where needed, would be applied to the strips thus isolated until the fly had got down to numbers that only hand-catching off screens could deal with; or the remaining flies would have to be made to appear by a localized eviction of their food-animals. Mr. Symes and the writer believe that the attack might be successful. If so, it would only remain to apply it to strip after strip, down the tributaries, down the main rivers to the Lake shore, along the latter and round the periphery of each island. We have recommended work on those lines to the Kenya Government.

The possible initial results of a few days' trapping on an island (Maboko, in the Kavirondo Gulf) are worth stating.

On the occasion of our first visit particularly (23rd May—Mr. C. B. Symes and myself) the flies had been quite pestiferous, and a fly-boy catching off himself on the 25th (when traps and some catching had already disposed in one small spot of well over 500 flies) captured there for three-quarters of an hour at the rate of 90 flies per boy-hour.

The traps had been set in an ideal and limited position—a small, open, mainly short-grass hippopotamus feeding-ground surrounded at the back by dense thicket and fronted by ambatch and the Lake. In the ambatch, at this very point, was a populous nesting site of egrets, darters and cormorants, the bushes being full of their nests and with eggs and young birds in all stages, and below the nests was a haunt of crocodiles.

Over 540 flies were caught, as stated, between the dates mentioned above (266 by an SS trap—Pl. i, fig. 4) and a further 480 at least to the morning of the 27th (361 by an SS arranged as a PS—Pl. i, fig. 2). It is possible that numbers more were taken by the dragonflies which attended each trap in a flock continuously, hovering head-on

to its screen. On the morning of the 27th there was a burst of attack by the flies, when Dr. Trim and the writer landed, and thereafter we saw relatively few. From this date to the 30th the catch by the traps had fallen greatly and the writer saw very few flies here indeed throughout that day's stay. Traps were moved on the 30th to a point of the island 400 yards off, leaving the 6 ft. SS alone. On the 31st the only effective individual out of the traps at the point (a 4 ft. SS.) had caught 57, the 6 ft. SS, in the original position of the traps and without competition, only 30. The writer walked the 600 yard strip immediately served by the two sets of traps and saw only one fly. A boy-hour catch in the same spot and at nearly the same hour as before produced no flies and two only were seen in an hour. This catch, repeated on 1st June produced two flies only in half an hour, and the general scarcity was the same. The flies being trapped at the point had also fallen by half. Finally the 6 ft. trap was moved a few hundred yards in the opposite direction to a second hippo feeding-ground. It again began catching large numbers. On the second day after the trap had been evacuated from its first site the boy-hour catch there rose to 20.

A further possibly significant fact was the high proportion of the whole catch that were newly emerged flies, more females than males. It seemed as though (a) most of the old flies that were coming at all might have been taken already, (b) the circulation of flies to the feeding-ground was relatively poor, or replacement would have been quicker.

A yet further fact—less favourable—was that the proportion of all females to males in the traps was far lower than the writer had ever before known it. On the Kuja River the females for the whole catch of the 6 ft. SS. were 76%, (70 to 80 is its usual percentage with *pallidipes*). On Maboko they were only 30%. That it was not the fault of the trap was proved by other traps that had been shown elsewhere to be very attractive to females. In other words, either the males preponderated here or the old females were not appearing. That they were too well fed to appear was strongly suggested by the examination of a boy-catch of 38 flies, the mean hunger stage of which came out at 3.26, an exceptionally high average in the direction of repletion. The hunger value on the Kuja River was very much higher. The apparent result of the trapping was reminiscent also of our catching-out experiment by hand-screens in a block of bush in Shinyanga, in which males preponderated at first and the females gradually preponderated later, the total caught and the measured density of the fly all the time gradually decreasing. Whether on so small a space as an island or a strip of a river the destruction of the last flies would drag out too long if unaided, by hand-catching or by some destruction or driving-away of food animals, can only be found out by the experiment mentioned above. As regards the general disappearance of fly referred to, the flies may, of course, learn to avoid a place in which the dragonfly attack becomes intensive. This and other possibilities can be tested.

It has been arranged to continue the Maboko experiment in co-operation between the two Colonies as a definite attempt at extermination. Our own handiest island (Mugasiro) is reserved for an experiment with parasites.

5. General.

We have carried out, under Mr. H. M. Lloyd, an experiment on *scymnertoni* with, it is believed, a far more effective weapon than any catching-cage trap yet invented. It was for the reduction of a block of fly at Shinyanga, which (as reduced by clearings) is thirteen square miles in extent. Hand-catching screens, of the types already described in this paper (p. 73), were carried about daily in all the concentrating-grounds of the fly—all the places, that is, in which traps would be set—by young native boys, 40 in all, who were expert catchers of flies and who caught each fly off their screen as it came to it. These screens in effect and appearance were simply trap targets with the addition of the smell of man, progressive movement and

a far surer trap (the hand-net) than the catching-cage; a number of catching-cage traps were set also. A particularly active European Officer (Mr. H. Harrison) had it as his sole work to see that the boys did not idle. The fly had already been much reduced by other means and was concentrated practically entirely on short-grassed patches along the drainage glades, and in the course of 9 months this constant catching brought down the numbers taken daily by 90 per cent. The last 10 per cent. it proved impossible to bring any lower by catching—probably a few flies were coming in from outside the block; but the traps had ceased to take anything long before, and even the addition of bait cattle to the catchers failed to make any real difference to *their* catch. It is possible that no stationary "sight" traps now extant, merely swinging *in situ*, will effect so much as this against *swynnertoni* or *morsitans* unless used in large numbers (which would entail considerable expense) to make up for the lack of the smell, movement and catching-power added by the boys. The question whether this is so is to be tested.

In Shinyanga a block containing *pallidipes* and *swynnertoni* has already been cut off from the main belt; the clearings still have to be widened. Near Kazikazi what is practically already a natural island of *Berlinia-Brachystegia* savanna†—enclosed in the large fly-excluding thicket of *Beruda*, infested with *G. morsitans*, and called by us, from its shape, the "Tennis Racquet"—has been selected and its narrow "handle" connection (200 yards) with the outside fly is being barred. The first area measures about four square miles, the second two and a half, and in each a trapping-out experiment will be conducted by means of the appropriate traps of the SS and SR types; the Kazikazi experiment under Dr. Jackson, the Shinyanga experiment under Mr. W. H. Potts, Senior Entomologist. The first 50 SS *pallidipes* traps have already gone into their places in the Shinyanga experiment, and a hundred more are rapidly following. Experiments by Dr. Nash with his pupa traps are also being provided with an "island." The inter-colonial experiment planned for Maboko Island in Lake Victoria against *palpalis* has been mentioned already. Dr. Nash's system of radiating paths, with a trap as the spider in the middle, will be tested incidentally to the above experiments.

The experiments, though mostly not very extensive individually, should, with the larger and more advanced Harris experiment in Zululand and Mr. Chorley's continued work in Uganda, give us a clear idea of the promise which trapping may hold for each of the four more important species of tsetse.

The following figures collected by Dr. Jackson at Masiliwa from two standing catches by boys without screens of ten minutes each daily for 51 days in the same spot illustrate the general correlation between high evaporation and a raised catch of females. Livingston atmometers with white cups were used to measure the evaporation.

Evaporation (uncorrected but inter-comparable) ...	0-20 cc.	21-40 cc.	41-60 cc.	61-80 cc.	81-100 cc.
Number of females captured daily in ten minutes ...	2.1	1.6	3.3	5.7	9.6

The rule applies also to captures in traps. When the evaporation rate rises into the sixties trapping becomes productive. In October (if rains have commenced), or in November, the numbers fall off and during the rains tend to become negligible here even for *pallidipes*.

The following are some monthly means (corrected) for evaporation in Old Shinyanga :—

					1931	1932
					cc.	cc.
January ...	...	...	...	...	—	54
February ...	...	...	...	...	38	34
March ...	...	...	...	...	28	28
April ...	...	...	...	...	26	24
May ...	...	...	...	...	45	39
June ...	...	...	...	...	53	54
July ...	...	...	...	...	58	—
August ...	...	...	...	...	70	—
September ...	...	...	...	...	72	—
October ...	...	...	...	...	79	—
November ...	...	...	...	...	56	—
December ...	...	...	...	...	30	—

Dr. Jackson has carried out a very close investigation of hunger in the flies in relation to the physical factors and will shortly be publishing on the subject in detail. He finds, actually, that the best correlation appears to exist between hunger and relative humidity, better than between hunger and evaporation, and slightly better even than between hunger and saturation deficit. Hunger is high in *morsitans* and its females come appreciably to man in feeding-grounds only when the relative humidity is less than 40%. This represents as well the more productive conditions for trapping. Any experiment with traps should be accompanied by a daily measurement of the more important of the physical factors at a centre close by, with a view to arriving at a true explanation of the variations in the catch. The main influences affecting the latter indirectly are undoubtedly meteorological—far more than game—and the writer believes, with Mr. R. W. Jack, Chief Entomologist of Southern Rhodesia, that these climatic factors being unalterable by ourselves it will be difficult to obtain a long enough catching season, at least in some of the cattle-tsetse belts, to produce extinction of the fly, particularly perhaps in the Coast belt, with its general high humidity. About this also, however, we should know more next year.

O. Notes on the Setting of the Traps.

Our largest fly-belt in Tanganyika measures 300 miles in greatest breadth by 500 at its point of extreme elongation. It is obvious that to trap out a belt of this size, or a belt of a twentieth of its size, if the traps had to be set closely all over it, would demand an amount of money which no Government would be likely to provide.

Dr. C. H. N. Jackson, particularly, has spent much time on the study of fly-concentrations with the special object of seeing whether the number of vital spots at which the fly can be attacked by trapping or other methods might not actually be so few as to make attack practicable. He and Dr. Nash independently in different fly-belts, have shown a *morsitans* area to be divisible into (a) the "home" of the fly, in mainly *Berlinia-Brachystegia* wooding, where the breeding goes on but the flies are replete and practically only the males show themselves; (b) the flies' feeding-grounds. A fly, having fed in one of these last, returns to "he" "home" for some days—four or five in the late dry season as against a hunger cycle in the big rains which runs, Jackson computes, to nine or eleven days and might run to fifteen, evaporation being then at its lowest and the fly seeming never to get empty. Failing to chance on food in the home, as it once more grows hungry, the fly wanders again and, reaching a feeding-ground, stays there or ranges along it, following especially paths, till it finds a meal.

The flies that come most to these feeding-grounds are young flies (very ravenous) and hungry adults—flies, that is, that are likely to enter traps—and an unusual proportion even of the flies caught by hand without screens in such places are females.

In some areas—in Nigeria and Southern Rhodesia more than in the Tanganyika belts studied—late dry-season concentration takes place also in the form of the evacuation of parts of the fly-belt and the crowding or leaving of the fly in the country round particular feeding-grounds or groups of feeding-grounds, riverine thickets, etc. Feeding-grounds at that time of year in any case show an increase in the fly found in them through the fact, noted by Jackson, that the flies in the neighbouring bush get hungry more quickly, it being a period of intense desiccation, and visit them oftener.

There is evidence too that young flies and hungry flies generally move particularly freely and far, that hungry *palpalis* ranges freely along the Lake shore, and an impression that *pallidipes* is a specially bold and strong ranger.

From every point of view, therefore—that of finding flies at their most concentrated and that of the necessary hunger to bring the females to traps—the feeding-grounds are the places to trap in. They may be enumerated as open, short-grass glades, whether drainage valleys or other, in woodland, the edges of larger vleis and mbugas (dambos), pans of water and water-holes frequented by game, even (and especially) for some time after their drying and the departure of the game, game stamping grounds, any other open space with short or no grass and good visibility, particular stretches of particular roads and paths, passages between or through thickets when these are traversed by game and much used or intersecting game-paths in a more or less open space. A limited open space of whatever origin, with a path or paths running through it, open passages or paths down to it and short or no grass, is probably the best of all, the traps being set where the passages enter it, or, if the space be quite small, in the middle, but any of the above-mentioned places may be excellent. Where, however, the potential feeding-grounds are large in proportion to the bush-area "home" that they serve, the hungry flies to be met with at any one point may be small and a large number of traps have to be employed to get the same number of flies as a few traps might get from more compact sites.

The foregoing has been written with *morsitans* primarily in mind. It applies also, however, to any of the other tsetse with minor variations only. Thus *pallidipes* appears to range along the outside of thicketed streams, whether the thicket be evergreen or, like nearly all thicket in Shinyanga, very completely deciduous, and along lines of thicket and close forest generally, visiting *en route* places of the kinds enumerated for *morsitans*; to some extent even leaving the thicket lines to visit or follow the latter or series of hard-pan patches where the two do not run side by side. *G. swynnertoni* is found congregating on these patches of hard-pan following drainage lines, with a very short, scanty, wiry grass. These aggregations are seldom pure feeding communities in the *morsitans* sense, for, as a rule, the general male population mingles in these places with the hungrier elements. The same thing has been noted for *morsitans* at some glades near Kilosa. Only two typical feeding-grounds are known for *swynnertoni* and each is associated with a road; but these two re-form each year. *G. palpalis*, though ranging along its rivers and shores, also (and particularly, Mr. Symes writes) comes to traps in open spaces, such as a relatively narrowly-cleared ferry or a small hippo feeding-ground hemmed in with bush and with the usual sunken hippo-path running into and out of it. Patches may be specially cleared or a path be made connecting these lake-side and river-side openings, as we did in Maboko and on the Kuja. Mr. C. W. Chorley finds that *palpalis* follows paths well; probably basking places of crocodiles and sandy coves will prove good also.

Open spaces can probably be made artificially for any of the tsetse concerned, and paths made radiating out from these or from natural concentrating-sites should, as Nash has shown in an experiment lasting four months, be useful for bringing the flies in to the trap at the centre. On the other hand an experimental trap on a man-used path is likely to show vitiated results through the transference of flies from natives who pass the trap or keep stopping to look at it. A source of mystification

might arise from the likelihood that game animals standing near an indifferent trap or a trap indifferently sited may raise its catch very greatly, as happened in Mr. Moggridge's experiments with the traps and the cattle (p. 91).

The trap should be hung from a sufficiently strong wire (say 14-gauge) extended between trees or between posts let into the ground. It should not be appreciably shaded but should stand out as boldly and conspicuously as possible. Its bottom should be, say, a foot from the ground, and the latter should be cleared of herbage and obstructions to view, both to make the spot more attractive to the fly and to help keep out the grass-fires. Traps set judiciously in hard-pan need little protection. Traps set elsewhere often need much more than can be afforded by merely "scuffling" close round them.

A trap set across the line of a path took many more flies than a similar trap set along it during a fortnight. This seems natural and, pending fuller special experiment, the writer follows this principle generally—the setting of the traps across the line, path or other, that the tsetses may be expected to follow. When in doubt as to this, the background against which the trap stands out best may perhaps be allowed to settle the matter. No definite evidence of the value of a particular orientation of the traps in relation to the sun has been noted.* Naturally in comparative experiments between different traps the orientation must be the same. Siting generally is of the first importance and no one without knowledge of the habits of the tsetse can expect to trap them successfully.

While wires from the corners may be used to suspend the trap from the wire overhead, it has seemed lately an excellent plan, following Mr. C. W. Chorley, to suspend each trap from a bicycle hub which itself is hung by a wire or wires from the horizontal wire above. Even when no spinning apparatus is placed on the trap, the latter, hanging from a hub with ball-bearings, is given such free and wild movement in any breeze that its conspicuousness is greatly enhanced. But the hub costs two and sixpence. The full Chorley-spinning apparatus consists of two light wooden rods that cross each other at right angles on top of any trap and are fastened to the latter, with a petrol tin, bisected diagonally, suspended by nails below each end of each rod (Pl. iii, fig. 2). These catch the wind like the cups of an anemometer and keep the trap moving round while giving also the impression themselves of progressive movement. It has not actually been proved by ourselves how great an advantage all this movement may be or not be, but it seems that it ought to be useful.

The bigger the trap the better it seems to catch, other things being equal. The wire or wires above should at some point be smeared with bird-lime to keep the ants from the trap should these be troublesome. Corrosive sublimate on strings wound round the wire has not been tried in this connection but may serve for a time in dry weather. Mr. Harris will probably not mind my saying that he uses a small tin (*e.g.*, a milk-tin) through a hole in the bottom of which a descending wire is passed, the hole then being soldered; bird-lime or an equivalent substance can then be placed in the tin. This ensures long-lasting protection. Where lizards are troublesome, jumping on to the trap and climbing up into the catching-cage, the trap may be hung higher, unless the stage has been reached where to obtain a count of the flies is not important. It is possible, in any case on the Lakes, that dragonflies by attending the traps may reduce the numbers of the flies that the latter would take. Spiders are liable to enter the catching-cages occasionally.

The flies are sprayed with "Flit" before extraction from the cages. Preparations of this type kill tsetse rapidly, but there is a strong doubt as to whether, if employed often, they do not reduce the catch. Cloth that fades appreciably should at once be replaced, but cloth that will not fade early should be obtained if possible.

* Indications have been obtained since and a number of other new conclusions have been arrived at by Mr. W. H. Potts, Senior Entomologist, continuing the trapping in Shinyanga. These will be published later.

A productive trapping ground for *palpalis* is shown in Pl. i, fig. 2, and one for *pallidipes* in Pl. i, fig. 3, and Pl. ii, fig. 4.

P. Summary.

1. More than twenty new forms and variations of tsetse traps are described in this paper for trial, and rejection or improvement, by other investigators. The species of tsetse-flies that they have been tested against have been *palpalis*, *pallidipes*, *morsitans* and *swynnertoni*.

2. The reactions of the various tsetse-flies to different forms of trap vary in a marked manner. Thus a trap (the Harris) that is excellent for *pallidipes* has appeared less good, though fair, for *palpalis*, poor (except at one season) for *morsitans*, and useless for *swynnertoni*. Another (the SS and the SSB) is particularly excellent for *palpalis*, excellent for *pallidipes*, mediocre for *swynnertoni*, and perfectly useless for *morsitans*.

3. Tsetses, *pallidipes* in particular of the two species tested, have been found to react also most strongly to the scent of an invisible animal placed in a trap. It is not known yet whether this attracts at a distance or is merely a close-range attraction, inciting the flies that have arrived in any case to such effort as takes them in larger numbers into the traps, but the latter does undoubtedly happen.

4. If the attraction be long-range, the flies do not readily distinguish between the source of the odour and conspicuous objects within its range. They go to and into a trap, even a trap that usually does not catch them, in greatly enhanced numbers when cattle are in its neighbourhood.

5. The best of the traps have been these :—

(a) The hand-catching screen, carried and caught off by boys, which is very highly effective.

(b) The SS trap with its variant the SSB; excellent for *palpalis* and *pallidipes* (Diagram 1; Pl. i, fig. 4; and variants, Diagram 3, fig. 7; Pl. ii, fig. 1).

(c) The roller or "moving staircase" trap (SRi and ii, BSR and SVR). The SRi and BSR have caught *swynnertoni* most promisingly, the SRii *morsitans* and *swynnertoni*, and the SVR *morsitans* and *pallidipes* (Diagram 3, figs. 14, 16; Pl. ii, fig. 2; Pl. iii, figs. 1, 2).

(d) The animal scent traps, SU and DLA (Pl. ii, fig. 4; Pl. iii, fig. 3), which have caught regularly two or more times as much as their controls of *pallidipes* particularly and many times more than the SS and Harris traps. There are difficulties as to the extended use of these scent traps until we can produce an inanimate substance with an equally attractive scent.

(e) The electric trap for the backs of lorries, guards' vans, etc. (Diagram 4; Pl. ii, fig. 3). Two field trials only up to the present, both most promising. It has proved impossible to kill tsetses with a voltage utilisable in practice, but they are stunned and fall into a tray with some oil in it, in which they rapidly die.

In addition the JV trap (Diagram 3, fig. 13; Pl. i, fig. 3, on right) has done well against *pallidipes* and caught fair numbers of *swynnertoni*, as has the SY trap. A suggestion has arisen (PCM trap, p. 90) as to the possibility of trapping tsetses in paths and passages through thicket by merely intercepting them with catching-cages.

6. The Harris trap (Pl. i, fig. 3, left) has been tested and found excellent here also for *pallidipes*; less good for the other species and apparently not better for *pallidipes* than some of our own traps, which are very much cheaper to make.

While these facts seem to preclude our present extended use of Mr. Harris's trap, the lead he has given investigation in a thoroughly useful direction by his invention of it is very warmly acknowledged.

7. Success in trapping with sight traps depends on hunger conditions. This is markedly so for *morsitans*, *swynnertoni* and (perhaps less) *pallidipes*, apparently considerably less so for *palpalis*.

8. It is believed that *palpalis*, with its linear distribution and its readiness to come to traps even in the rainy season, will be a particularly favourable subject for attack by trapping. *G. pallidipes* is certainly the next most favourable, and *morsitans* and *swynnertoni* the least so; but we have at last promising traps for them, and the chief remaining difficulties are those of the limited hunger-season and the great extent of the fly-belts.

9. Hunger depends primarily on meteorological conditions—on the atmospheric humidity apparently in particular; secondly, on the presence of food animals. Hunger is high in the late dry season, practically absent in the rains, especially April. These facts limit the catching-season, and it is believed that only in a year of exceptional drought could a year-round campaign be effective against the two tsetses last mentioned, at least under our conditions.

10. Even for *palpalis*, against which trapping is strongly recommended, a further measure will perhaps have to come in at the end—the use of natives with hand-catching screens, or the scent traps, or a localised destruction of food animals.

11. To test these points and the exterminative value of trapping against the various flies, three isolated areas, from $2\frac{1}{2}$ and 4 square miles in extent upward, have been selected or separated for trapping-out experiments under trained entomologists against the following species of tsetse-flies, in the adult and pupal stages: *morsitans*, *pallidipes*, *swynnertoni* and *palpalis*.

The *palpalis* island is in Kenya and the work on it will be conducted in co-operation with the Medical Entomologist, Nairobi. The others are in Tanganyika. Traps of the SS and roller types, and Dr. Nash's pupa trap, will be used amongst others.

12. In the writer's opinion neither the Harris trap nor our own traps, excellent though both are, nor other traps based upon sight, are likely to represent the last word in tsetse-traps. The next big object to be worked for is the production of a scent, attractive to the flies, that is not dependent on the presence of an animal and not too evanescent for use in the traps. Such a scent will probably best be combined for tsetses with such cheap trap forms as our concentrative SS, JS, or SY traps, the crinoline form (suspended and otherwise) and some of the traps in use for blowflies, these all costing only a few shillings to make.

ADDENDUM (25th January 1933).

The most recent experiments on Maboko Island and in Shinyanga respectively have emphasised the paramount importance of the expert siting of the traps. One trap sometimes catches magnificently, while another of the same type a few yards away catches almost nothing; one kind of trap catches well in one kind of situation, another only catches well in another tapping a different fly-stratum.

The doubling of the cheap "bicycle" gearing described on page 84 has proved very effective in procuring easy starting and slow movement of the drum traps.

Evidence is accumulating of the probable great importance of scent, and Mr. C. B. Symes, Medical Entomologist, Kenya, has made extracts, in alcohol and in ether, from the sebaceous and other glands of a steer and a bull which, placed in small quantities in SSB concentrative traps on Maboko, resulted on each of the days on which they were tried in a doubling or trebling of the catch and lasted well over a week. Mr. Symes will be publishing an account of this preliminary experiment. Should his discovery be further developed as we hope, every form of trap described in this paper can be used as the foundation of a new scent trap, and the trapping of tsetses perhaps be revolutionised.

The "cave" trap, produced by laying a crinoline trap (like that long used for mosquitos, but with a gauze non-return catching cage, partly suspended) on its side in the edge of the breeding-grounds, also made promising catches of *G. palpalis*.

Milambo, the head fly-boy on Maboko, has found that in certain situations an S\$ trap laid on its side catches very many more flies than when vertical. This has led to the evolution of a broad and particularly conspicuous "cave" trap, which may be useful.

As the result of a conference in January 1933 on Maboko, an exchange of ideas and observations, and two days' joint experimentation between Messrs. C. B. Symes (Kenya), G. R. Hancock and C. W. Chorley (Uganda) and the writer (Tanganyika Research Team), it was felt that the chances of dealing effectively and relatively cheaply with *G. palpalis* have grown. A co-ordinated programme was decided on.

In general, close, friendly and already fruitful co-operation has been inaugurated between the three colonies during the past year in the matter of the work against tsetse-flies.

* For the crinoline trap see, *inter alia*, Government of India Health Bulletin, no. 11, 1927.

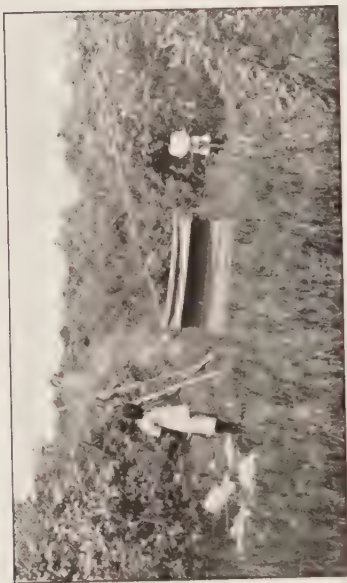


Fig. 2.



Fig. 4.



Fig. 1.



Fig. 3.

Examples of traps for catching Tsetse Flies.

EXPLANATION OF PLATE I.

- Fig. 1. Original catching screens used since 1922 for catching with bird-lime and by hand.
- .. 2. An SS (single screen) trap arranged as a PS (plain screen) trap with the awnings vertical, in a hippopotamus feeding-ground on Maboko Island, Kisumu, where it made a large catch. An example of a good site for trapping.
 - .. 3. Harris trap (left) and Jackson (JV) trap (right) to show difference. In the Harris trap the flies enter the target through the opening along the belly and pass through it to the catching-cage above. The JV (and SV) target is completely closed or completely open and the flies pass up the outside into catching-cages slung from its shoulders, like a ship's boats.
 - .. 4. The individual SS adjustable 6 ft. trap which did well against *Glossina palpalis* on the Kuja and Maboko. On the left rear is shown the horizontal position of the awning, on the left front the erect position of the awning which makes the trap into a PS trap. On the right is shown the more usual slightly dependant position of the awning.

EXPLANATION OF PLATE II.

- Fig. 1. A group of recent SSB ("Buttock") traps, the nearest one actually an SS without buttock, one with a gauze buttock and one with a hessian buttock.
- „ 2. A roller trap with large drum and no screen (SRii—p. 84). The "brush" (in this case of felt) is shown. The awning support beyond on the left is one of a pair, the hessian awning on which, 3 inches away from the drum, acts as a guard to prevent the flies from flying out. In this photograph the drum hangs too low.
- „ 3. The electric trap mounted on the tail-board of a motor lorry on the occasion referred to on p. 87. The tray below it is shown. The white cloth on the top was to deter flies from settling on the top of the tail-board.
- „ 4. The DLA animal-trap (right) and its control (left) on the day on which the former took 584 flies in $5\frac{3}{4}$ hours. This photograph and Plate I, fig. 3, together give a nearly complete picture of a small natural open space in the bush, with a path (not shown) running through, and a riverine thicket on its west, that produced a great number of *pallidipes* over a fortnight's catching and is now (August 1932) repeating that performance, its largest catch being 1,200 flies in one day (*cf.* pp. 88 and 91).



Fig. 2.



Fig. 4.



Fig. 1.



Fig. 3.

Examples of traps for catching Tsetse Flies.

EXPLANATION OF PLATE III.

- Fig. 1. A roller trap with dependant screen (SRi—p. 83). The grey strip attached to this trap was too light.
- „ 2. A “ moving staircase ” (BSR) trap with two cylinders round which the screen climbs, in an open space in *morsitans* country (Kazikazi).
- „ 3. The SU animal trap. This replaced the DLA trap shown on Plate II, fig. 4, and continued catching with equally good results.

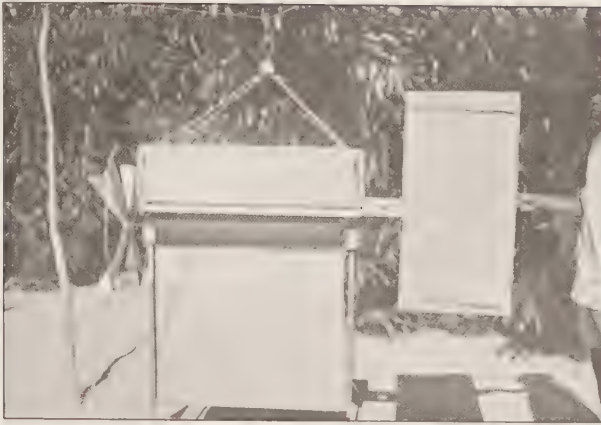


Fig. 1.



Fig. 2.



Fig. 3.

Examples of traps for catching Tsetse Flies.

THE ECOLOGY OF *GLOSSINA MORSITANS*, WESTW., AND TWO POSSIBLE
METHODS FOR ITS DESTRUCTION.—PART I.

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INTRODUCTION.

Much of the first part of this paper is in the nature of a continuation of the work previously published by the author. (*Bull. Ent. Res.*, xxi, 1930, pp. 201–256). For this reason only a brief description can be given of the locality, vegetation, game, and fly-round methods; those desiring a fuller knowledge on these subjects are referred to the above-mentioned paper. Again, a certain amount of repetition has been unavoidable. Some results obtained from only one year's observation have now been confirmed during a period of four and a-half years, and so have been given again. It is felt that this repetition is justifiable as the results in question are of special value, in that they are derived from four and a-half years continuous observation upon the same fly-belt, the method employed being constant throughout the whole period.

The writer is in charge of Kikori Entomological Station, which he opened in March 1928; nine months later he was joined by his assistant Captain V. A. C. Findlay.

The native village of Kikori is situated at the foot of the Masai escarpment, which bounds the Masai Steppe on the west. Kikori lies about 45 miles north of Kondoa-Irangi (the principal centre of the district), its approximate bearings being Latitude 4° 21' S. and Longitude 33° 19' E.; its elevation is 4,158 feet above sea-level. This village is situated in the densest part of the Kondoa Eastern Tsetse-fly belt, which is represented by a linear strip of country running along the foot of the escarpment and having an average width of approximately seven miles. On the east it is bounded by a grassy plain known as the "Great Mbuga;" owing to the scarcity of fly above 5,000 feet, the western limit is formed by the escarpment. The northern and southern limits are formed by unsuitable vegetation.

Kikori was chosen as a research station for the following reasons:—The fly density can be very high. The bush is laid out in almost diagrammatic order from the rain forest covering parts of the top of the escarpment, down to the open grassy plains of the Masai Steppe. Hence in a very small area fly can be studied in a large number of typical, well-defined, vegetational habitats. Many species of big game are represented in this district, ranging from the greater kudu of the hills down to the brindled gnu and gazelles of the steppe.

There are certain unusual terms that must be employed throughout this paper for the sake of brevity, because there is no one English word that is synonymous. Again, other terms have been coined in order to describe certain fly areas; the meaning of these terms is obvious, but additional explanation will simplify their use.

"*Mbuga*." This is the native name that describes areas of low-lying land that in the dry season are characterised by hard, cracking, "black cotton" clay, and in the wet season by becoming marsh-land.

"*True Habitat*." The true habitat is the breeding area of the fly, and is capable of satisfying its requirements at all times of the year. It is also an apparent male area, females rarely appearing to man, though abundant. *Brachystegia microphylla* and *Berlinia* wooding form the only true habitats in the district.

"*Feeding-ground*." The feeding-grounds are areas to which hungry fly resort solely for the purpose of feeding. Probably these fly have failed to find food in the habitat and so have been forced to look for it elsewhere. Such areas are characterised by a high percentage of freshly emerged or young fly, and a relatively high female percentage. Feeding-grounds occur in "mbugas," and along roads.

"*Fly Density*." No pretence is made of giving true fly density figures, such figures being unobtainable. It must be understood that the figures given only yield an apparent fly density. That such figures afford a perfect index of true density will be proved later (p. 126).

"*Fly-Round*." A fly-round, of the type used by the writer, is a survey of tsetse-fly over a fixed route, repeated at definite short intervals throughout the year.

"*Vlei*." (As defined by the Editor of the *Bulletin of Entomological Research*, 1911) "A term used in South Africa for open, low-lying land, which is always marshy during the rains, but which may or may not be dry during the dry season." N.B. Very similar to an "mbuga," but a "vlei" is usually a small open depression surrounded by woods. An "mbuga" may cover an enormous area, and is almost always dry in the dry season.

"*Kopje*." A great mass of rock set in the middle of a plain, or in undulating country; it may be two or three hundred feet in height.

The climate may be divided into two dry and two wet seasons.

(1) *The Long Dry Season*. This, the true dry season, begins at the end of the heavy rains in early May. It is characterised at Kikori by the following features:—For a considerable period after the heavy rains have ended the sky remains overcast until mid-day or later, and there may be a fine drizzle until 10 a.m. The night temperature gradually drops, until in June or July it reaches a minimum. The temperature then rises slowly, and the number of hours of sunshine increases; the deciduous vegetation becomes leafless, and the grasses are tinder-dry; a period of bush fires ensues.

(2) *The Early or Light Rains*. These rains break in late October or early November, when the vegetation bursts into new leaf; the young grass shoots up and the natives cultivate. A maximum mean monthly temperature is reached in November. The rainfall varies considerably from year to year.

(3) *The Short Dry Season*. The first rains gradually cease in early February, when this season begins; it finishes towards the end of the month. The fact that it is a dry, hot period is masked by the monthly meteorological statistics, which show comparatively high rainfall and low temperature owing to the commencement of the heavy rains at the end of February. The short dry season only extends for two or three weeks and is little more than a break in the rains; however it is characterised by extreme heat which, after poor early rains, can dry up the young grass and even produce a recurrence of bush fires.

(4) *The Heavy Rains*. This season extends from late February until early May. The ground becomes sodden in the "mbugas," and grasses may attain a height of 5 to 8 feet.

In the accompanying Tables it will be noticed that the monthly data and yearly totals are not arranged by calendar years, as is conventional. The season is taken as starting in September of one calendar year and as ending in August of the next.

This is done because the new biological season is not ushered in by New Year's Day, but by the advent of the early rains in October. All instruments are kept at a height of four feet from the ground. The temperature and humidity data have been obtained from instruments kept in a Stevenson Screen.

From June 1929 until August 1930 the temperature data were obtained from maximum and minimum thermometers. After this date a recording thermohygrograph was used. Hence, in the mean monthly temperature figures (Table III) only the readings for the last two years are accurate; the figures for the first fifteen months are mere approximations, being obtained by averaging the maximum and minimum temperatures.

The meteorological records of humidity are expressed throughout this paper as saturation deficits (Table VI). The notation of relative humidity percentage was given up by the writer on the advice of Dr. J. Phillips. Relative humidity percentages are only comparable among themselves provided that the temperature is constant. Hence for field observations on humidity where the temperature is always varying relative humidity percentages are of little value. Blackman, at the Conference of Empire Meteorologists (1929), stressed that from the agricultural stand-point one requires the saturation deficit of the air, for on this depends the water loss from the plant. The saturation deficit gives a measure of the dryness of the air, and is better than relative humidity in that it gives an absolute and not a relative value.

The evaporative power of the air is measured by a Livingston-thone, white, spherical, cup atmometer (Table V). The meteorological plot is situated in thin fly half-way between the two fly-rounds. Grass is allowed to grow up naturally around the instruments and is burnt at the time of bush fires, so that fairly natural conditions prevail.

TABLE I.

Mean Monthly Maximum Temperature of Kikori Entomological Station. °F.

Year	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	Period months	Average
1928-29	—	—	—	—	—	—	—	—	—	77·20	75·60	79·27	3	—
1929-30	83·22	87·35	87·26	84·86	82·94	80·84	80·22	78·59	75·17	74·95	74·81	76·55	12	80·56°
1930-31	81·96	84·44	85·24	85·50	86·00	86·80	82·31	80·80	76·15	75·18	76·81	78·11	12	81·61°
1931-32	82·43	82·35	88·57	81·11	83·81	83·46	81·48	78·35	74·03	73·05	73·78	76·48	12	79·91°
Monthly means ...	82·54	84·71	87·02	83·82	84·25	83·70	81·34	79·25	75·12	75·10	75·25	77·60	39	80·81°

TABLE II.

Mean Monthly Minimum Temperature of Kikori Entomological Station. °F.

Year	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	Period months	Average
1928-29	—	—	—	—	—	—	—	—	—	53·52	55·79	55·23	3	—
1929-30	57·44	60·83	63·02	63·06	61·97	62·35	62·86	62·25	58·76	52·81	50·99	54·62	12	59·25°
1930-31	57·65	59·82	63·58	62·23	63·32	64·38	64·82	63·98	61·07	55·69	56·89	57·33	12	60·98°
1931-32	57·98	56·14	61·98	63·37	62·44	61·22	62·91	63·66	61·70	57·70	54·01	56·51	12	59·97°
Monthly means ...	57·69	58·93	62·86	62·89	62·58	62·65	63·53	63·30	60·51	54·93	54·42	55·92	39	60·02°

TABLE III.

Mean Monthly Temperature at Kikori Entomological Station. °F.

Year	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	Period months	Average
28-29	—	—	—	—	—	—	—	—	—	65.36	65.70	67.25	3	—
29-30	70.33	74.09	75.14	73.96	72.46	71.60	71.54	70.42	66.97	63.88	62.90	65.59	12	69.91
30-31	69.81	70.63	72.18	72.21	72.65	70.92	71.32	69.94	66.87	63.27	64.46	65.97	12	69.49
31-32	69.68	67.70	73.30	70.37	70.91	70.36	69.79	68.50	65.96	63.19	61.80	64.33	12	67.99
Monthly means ...	69.94	70.81	73.54	72.18	72.01	70.96	70.88	69.62	66.60	63.93	63.72	65.79	39	69.17

TABLE IV.

Rainfall in Inches, by Months, at Kikori Entomological Station.

Year	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	Period months	Total
28-29	0.00	2.25	0.47	3.76	1.70	0.50	5.38	5.90	0.65	0.03	0.05	0.11	12	20.80
29-30	0.16	0.94	0.31	6.88	7.66	6.95	9.75	13.33	5.09	0.06	0.25	0.01	12	51.39
30-31	1.66	0.27	4.23	1.25	5.83	4.13	6.85	7.84	2.50	0.12	0.00	0.00	12	34.68
31-32	0.08	0.00	0.76	9.16	3.73	5.81	12.62	11.23	4.75	0.06	0.03	0.00	12	48.23
Monthly means ...	0.48	0.87	1.44	5.26	4.73	4.35	8.65	9.58	3.25	0.07	0.08	0.03	4 years	38.76

TABLE V.

Mean Monthly Evaporation in ccs., using a Livingston-thone, white, spherical, cup Atmometer.

Year	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	Period months	Average
28-29	—	—	—	—	—	—	—	—	—	25	27	37	3	—
29-30	48	54	49	33	24	14	11	7	12	18	21	25	12	26
30-31	30	50	48	42	37	36	25	21	17	21	27	39	12	33
31-32	51	59	65	31	29	29	22	17	20	18	22	31	12	33
Monthly means ...	43	54	54	35	30	26	19	15	16	21	24	33	39	31

TABLE VI.

Mean Monthly Saturation Deficit in Millibars.

Year	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	Period months	Average
30-31	—	11.06	8.42	7.98	7.82	8.21	4.44	4.07	3.42	3.61	4.99	7.17	11	6.47
31-32	9.62	12.12	14.15	5.77	6.06	5.74	4.27	3.01	2.85	3.27	3.98	6.10	12	6.41
Monthly means ...	9.62	11.59	11.29	6.88	6.94	6.98	4.36	3.54	3.14	3.44	4.49	6.64	23	6.58

I. FLY-ROUNDS.

Many types of fly-rounds have been invented from time to time by various workers studying different species of fly. Methods of studying fly numbers were first introduced by Carpenter and Fiske when studying *Glossina palpalis* (Carpenter, 1912, 1919; Fiske, 1920). The subject has recently been reviewed by Potts (1930). The writer employs his own method, which he has described in detail (Nash, 1930), because of the extremely satisfactory results that it has given. Early in 1928 fly-rounds were set out, in order to tap the main vegetation types of the district. Each round was divided into sections by numbered trees, which mark the limits of each type of vegetation.

Two such rounds were instituted at Kikori, and are called the N.E. and S.E. Kikori fly-rounds; the former is divided into twelve sections, the latter into ten. Both are about seven miles in length. A twelve mile round was made at Kandaga, a village twenty miles south of Kikori. It serves as a control to the Kikori rounds, and is divided into twenty-one sections.

It has been found that six readings for each round can usually be obtained in five weeks. These are carried out at three different periods, at about ten-day intervals. The two readings for the same period are purposely separated by the interval of a day, lest the displacement caused along the route by the catching should not be rectified on the following day by the inflow of fresh fly. In order to even-out the results, the rounds are not started at the same end on each of the two days, and the figures plotted on the graphs are always the means for each period.

The number of catchers is kept constant, and is always two. The two catchers walk about twenty yards in single file and then stop. The second boy having caught off the back of the first, both "about turn," so that the first can examine the back of the second. They then search the ground within the radius of a yard from where they are standing for fly that may have settled there. Having finished, the catchers then walk another twenty yards and repeat the performance.

Fly-rounds of this type yield information as to the seasonal variations in density and breeding activities; the seasonal distribution of fly in different types of bush; the effects upon fly of game movements and grass fires; as well as upon many incidental points likely to be of value. The writer considers that a fly-round, carried out regularly, is an essential piece of routine work that must accompany research or experimental reclamation, as it enables the observer to keep his finger upon the pulse of the fly community. Tremendous natural calamities may overwhelm the fly population (see p. 113), but without fly-rounds the observer would be at a loss to explain the sudden disappearance of the insects.

The 'flies per boy-hour' unit, employed by Fiske (1920) and many others who were working upon *Glossina palpalis*, is considered to give fallacious results when used for the expression of density of *G. morsitans* (Nash, 1930). For this reason, the writer uses the unit "flies per boy-yard" throughout this paper. Since the length of the fly-round paths is known, one has the two constants: distance and number of catchers. Fly density, as expressed by this F.B.Y. unit, can readily be obtained from the following formula:

$$\frac{\text{No. of fly}}{\text{No. of boys} \times \text{distance}} = \text{F.B.Y.}$$

In practice it has been found that the result works out at an inconveniently small figure, so it is multiplied by a hundred, making the unit "flies per boy—100 yards." Density figures are not based on males only as in Fiske's work on *G. palpalis*, since it is considered that this is only necessary for reconnaissance work. The writer will show later that there is but little seasonal fluctuation in the female percentage, the variation being mainly one of locality. Since the catches are always made along the

same fly-round tracks, the variations in locality are constant for the round. The density figures give the density of fly as apparent to man in this fly-belt. The density as it would appear to different hosts would vary according to the attractiveness of the host to the female flies. Should a buffalo be capable of doing fly-rounds it would obtain a higher fly density than would man, because more females would be attracted to the buffalo, and hence would swell the latter's total. Since only man is capable of doing fly-rounds, and since a man is carrying out this investigation, there seems to be little point in worrying about the increased number of females that would appear to a buffalo or to an ox. A fly-round done with bait cattle would be pointless as an indicator of fly density, as apart from the mixed nature of the bait due to attendant humans, the twitching of the beast's skin makes accurate catching impossible. It appears to the writer that as long as the bait is constant to two men, and the locality constant to the fly-round path, there is no need to worry about the increased activity of females towards other more attractive hosts.

1. A Yearly Review of all three Fly-Rounds, ignoring Seasonal Fluctuations (March 1928 to August 1932).

In figs. 1, 2, and 3, the upper curve is an index of fly density. Each point represents the mean number of fly caught on the two days that form a period. The lower curve gives the mean number of young fly caught in each period, and so gives an indication of emergence, and hence of breeding activity. If one compares the fly density year by year, and assumes that the higher the density the more thriving the community, one reaches the following conclusions :—

In 1928 the tsetse population for the whole fly-belt formed a flourishing community. Throughout 1929 and early 1930, one can say that the community was positively thriving. For the rest of the year, and for the whole of 1931 the tsetse population was clearly struggling against some severe calamity that had overtaken it in April and May 1931. It is not until early 1932 that the fly can be said to have recovered from the catastrophe that had overwhelmed it a year and half before. There can be no doubt as to the nature of the blow that almost exterminated the tsetse community on two of the three fly-rounds. It was in April and May 1930 that the torrential rains of that year reached their climax. Towards the end of April ten inches of rain fell in eight days, an amount equal to half the total rainfall of the previous year. These abnormally heavy rains were not local ; they occurred all over the Territory, and resulted in serious flooding that washed away large sections of the railway line, and rendered road communications impassable.

The fly may have been affected in one of three ways, or in all three ways combined.

1. By the extermination of the old flies owing to the unsuitable meteorological conditions. For seven consecutive days in late April the atmosphere was saturated, no evaporation taking place. It will be shown later that too low a drop in the evaporative power of the air is followed by a drop in fly density. Roubaud (1909 a) found that *G. palpalis* reproduces normally at 70% relative humidity, but that a humidity of 100% arrests reproduction.

2. By the incidence of an entomophagous fungus that produced black spots on the lower side of the abdomen of tsetse. Mr. Scott, formerly of this Department, did some work on the fungus and proved that it was definitely pathenogenic to *G. morsitans*. At the end of April the fungus was found to have infected as many as 20% of some catches of fly ; the fungus is in the Phycomycete group. The writer was unfortunately on leave at this time, and so was unable to keep detailed records of the number of fly infected, from the fly-round catches.

3. By part of the plains being inundated for some weeks, and most of the bush water-logged. It seemed highly probable that submergence of tsetse puparia might prove fatal.

In order to determine whether this was the case the two following experiments were carried out :—

(a) *Experiment to find out the effect of inundation.*

Two hundred and sixty puparia were used for the experiment, and another fifty were kept as controls. Batches of ten puparia were placed in water for periods varying from one hour to fourteen days. At the end of the submergence period for the batch, the puparia were carefully removed, dried, and then placed on cotton-wool in tubes, and the emergence noted. The results are given in Table VII.

Clearly a submergence of up to four days is not fatal to tsetse puparia ; above four days it is fatal in every instance.

The emergence percentage of all puparia that emerged after exposures varying from one hour to three days was 73%, as against 84% for the controls. Obviously the puparia used were healthy.

TABLE VII.

Duration of submergence	Number of puparia submerged	Number of tsetse emerged	Duration of submergence	Number of puparia submerged	Number of tsetse emerged
1 hour ...	10	7	1 day	10	10
2 „ ...	10	8	2 days	10	9
4 „ ...	10	7	3 „	10	4
6 „ ...	10	6	4 „	10	1
8 „ ...	10	5	5 „	10	0
10 „ ...	10	7	6 „	10	0
12 „ ...	10	10	7 „	10	0
14 „ ...	10	8	8 „	10	0
16 „ ...	10	8	9 „	10	0
18 „ ...	10	8	10 „	10	0
20 „ ...	10	6	11 „	10	0
22 „ ...	10	7	12 „	10	0

(b) *Experiment to find out the effect of water-logged soil.*

Two batches of twenty-five puparia were buried at one inch depth in two tins, fifteen inches high, that were filled with water-logged soil. No water was allowed to stand on the surface, but neither was it allowed to dry. One batch was exposed to this treatment for five days, the other for ten. No single puparium produced a tsetse either during the first five days or afterwards.

Presumably when the puparia were placed in the water-logged soil, the occupants realised that conditions were unfavourable for emergence, and since conditions continued unfavourable the fly succumbed before the fifth day.

It can be concluded that the puparia of *Glossina morsitans* cannot survive inundation or exposure to water-logged soil conditions for more than four days. The result suggests that riverine infestations of *G. palpalis* might be destroyed in suitable localities by damming the stream and flooding the banks for some distance on each side.

Returning to the main theme, it is of interest to note that the N.E. Kikori fly-round was not nearly so badly affected as the other two rounds. Both the S.E. Kikori and Kandaga rounds pass entirely through the plains, whereas the N.E. Kikori round traverses the *Brachystegia microphylla* hills for a portion of its length. Naturally the puparia deposited in the hills, under outcropping slabs of rock and in well-drained sites with sandy soil, are not going to succumb so readily as those puparia deposited under logs in the *Berlinia* woods at the foot of the escarpment. The dry years of 1928 and 1929 had enabled *G. morsitans* to push out into the plains, and to establish itself with a high density right up to the eastern boundary of the fly-belt—the great grassy steppe of Masai-Land.

In these favourable years fly breeding was very abundant in the *Berlinia* wooding, and even the unsuitable *Acacia usambarensis* woods became breeding areas of a sort. *Acacia usambarensis* is associated with heavy clay, and its communities are usually low-lying; for this reason it is unsuited for breeding, because the clay is too sticky in the rains, and too hard in the dry season. Despite this, the pregnant females living in this country found unusual breeding sites that sufficed. One such site was a great fallen *A. usambarensis* tree that was raised about one foot off the ground. The inside had rotted, but the bark on the upper surface was still in position, though loose. This bark was divided into two, forming a long crack, like the slit in a money-box. Removal of the bark displayed hundreds of tsetse puparia and cases, lying on the surface of the decomposing wood pulp. It was intended to keep this site under observation, so only 92 full puparia and 209 cases were removed. Unfortunately a bush fire burnt the log to ashes a few days later. Of the 92 puparia collected 21% were parasitised by Bombyliid flies (*Thyridanthrax* spp.). Such a site is considered unsuitable, as its puparia can be destroyed by fire or by sun when the bark falls off. Again the puparia are exposed abnormally to parasite attack. A similar site has never been found in recent years, and it is regarded as being evidence of the outward and injudicious spread that is attempted when the tsetse community is thriving.

Uvarov (1931) mentions that a species, when in large numbers, becomes less restricted ecologically than is usual. He cites the case of the locust, *Locusta migratoria rossica*, Uv. & Zal., in central Russia. Predtetchenskii (1928) found that this species normally breeds only in certain habitats, which are the driest and warmest in the region. After a series of abnormally dry and warm years the locust increases in numbers and invades other habitats as well, only to re-assume their "island" distribution on the return of weather conditions normal to the area. Uvarov points out "how such reservations, particularly suitable for a given species, owing to their ecoclimatic conditions, are a factor of great value in its survival throughout unfavourable years." The outward spread of *G. morsitans* during dry years, and its subsequent retreat to its true habitat, or *reservation*, after the wet year is a perfect example of insect *gradation*.

Inspection of the fly density figures on the N.E. Kikori round after the down-pour shows that a great reduction in density of the fly occurred in the *Acacia usambarensis* and *Combretum* savannah sections of the plains, whereas a much smaller reduction took place in the *Brachystegia microphylla* sections of the hills.

It will be seen that the effect of the torrential rains was even greater on the Kandaga round than on the S.E. Kikori. This was probably due to the fact that the latter round was gradually re-infested by the survivors that emerged in the neighbouring hills. The escarpment behind the Kandaga round is mostly unsuited to breeding because it supports 14 foot grass, so these hills were unable to form a source of re-infestation. The result was that Kandaga almost ceased to be a fly-belt. In early June the twelve miles of this round could only yield 22 fly of which 18 were freshly emerged. During May and June 63% of the fly caught at Kandaga were freshly emerged individuals, as against its average of 20% during three and a-half years. Clearly the fly community managed to survive and eventually recover, owing

to the fact that odd puparia must have been deposited in dry places. Kandaga is of great practical interest as a natural example of the extent to which fly density can be reduced without extermination resulting.

Having reviewed the whole position the writer is inclined to consider that the entomophagous fungus did not play the greatest part in the fly reduction. Had the fungus been of primary importance the N.E. Kikori round should have suffered equal reduction in fly density. A saturated atmosphere also occurred in the hills, so that the true habitat should not have escaped fungous infection more readily than the plains. Undoubtedly very high humidity is directly inimical to fly, in that reproduction may be temporarily arrested, and indirectly, because it favours the incidence of entomophagous fungi.

Supposing that for a fortnight some factor was active that exterminated every living fly, but was incapable of reaching the puparia, undoubtedly a great reduction in density would occur, but the following emergence from the thousands of puparia that had not been affected would soon make up the deficit in fly numbers. One would not expect a tremendous initial reduction, requiring nearly eighteen months before recovery was assured, as was the case at Kandaga.

Taking all things into consideration the writer concludes that the effect upon the fly community was primarily brought about by the destruction of puparia, owing to the inundation and water-logging of the breeding sites, and secondarily by the cessation of larviposition due to arrested reproduction.

Having studied these three graphs one cannot help wondering whether some of the sudden disappearances of fly that one reads about may not have been due to abnormal rainfall. For instance in Fuller's "Historical Review of Tsetse in the Transvaal" (1923), while dealing in his Conclusion with the disappearance of tsetse concurrent with rinderpest 1896-1897, he states "... while tsetse remained abundant in the low country between the Drakensburg foothills and the Lebombo range down to the time of the rinderpest, it had disappeared before that epoch from two-thirds of the territory it previously infected. Consequently, whilst it may be claimed with much reason that rinderpest led to the rooting out of the fly from the eastern region of the Transvaal, no occurrence of so cataclysmic a nature can be held to account for its vanishing from elsewhere in the Transvaal."

Jack (1920) went into the question of this particular disappearance of fly in the Transvaal, and consulted some meteorological returns from South African recording stations, but there was no indication of any unusual rainfall at this time. However, it is not the total precipitation that matters, so much as the distribution of rainfall (see p. 118). The writer has not been able to consult this paper of Jack's in the original, and so does not know whether that author paid any attention to this point.

Conclusions based upon a preliminary inspection of the yearly abundance of fly on the three fly-rounds.

1. The abundance of tsetse in a fly-belt varies from year to year.
2. It is suggested that in years of low rainfall the tsetse community flourishes, and that in years of abnormally heavy rainfall the fly population may almost suffer extermination.
3. That of the three factors correlated with heavy rainfall the submergence of the puparia is more detrimental to the race than the effect upon the adult of either fungus attack or an unsuitably low evaporation.
4. Exposure for over four days of the puparia of *G. morsitans* to inundation, or burial in water-logged soil, is fatal in every instance.
5. The rocky hills forming the true habitat of *G. morsitans* are probably of great value to the fly, in that they prevent its complete extermination by abnormal, heavy rainfall.

2. The Seasonal Fluctuations on all Rounds.

The yearly fluctuations in the abundance of tsetse on each round have already been discussed. The minor fluctuations due to the seasons that occur within a year will now be dealt with.

The N.E. Kikori Round.

The effect of season upon fly density is well demonstrated by the graph for the N.E. Kikori round (fig. 1). This fly-round gives the best data, because it is not subject to great game movements that can temporarily mask the effect of season, and because of the large size of the figures which it yields. Again, the N.E. Kikori round data are mainly obtained from the true habitat through which it passes, and can be looked upon as coming from the core of the fly-belt. Comparison of the other two rounds (figs. 2 and 3) with the N.E. Kikori round will show that they approach agreement throughout, but that big divergences occasionally occur. These divergences are readily accounted for, and will be dealt with later.

Looking at fig. 1, it will be seen that there are certain definite fluctuations in the curve that take place every year. Annually the fly density drops in the latter half of the long dry season (September and October), fly becoming scarcest in late October or November, when the early rains are breaking. Note how every year the number of fly caught on this seven miles of fly-round varies between one and two hundred. The degree of drop is nearly constant; the fly can decrease to a certain point, but no further. No matter whether fly was abundant or scarce earlier in the year, it will reach approximately the same low density in October and November.

The late dry season is the most constant of all the seasons. Every year the bush fires burn up the country-side, the trees become leafless, and the maximal temperature is attained. The writer believes that the constancy of this season, and the relatively small variations in meteorological conditions from year to year, account for the small variation in fly numbers. It must not be overlooked, however, that whereas fifty flies more or less at this period may appear of small importance, yet it may be of superlative value to the recovery of the community at such a critical period of its annual cycle.

The degree to which the fly increases, apart from this yearly and minimal fixed range, varies according to the variability of the climate. Other seasons vary greatly in duration, degree and intensity from year to year, and consequently the fly numbers are equally erratic. The increase in fly density that starts in the middle of the early rains and reaches a maximum point in February, the short dry season, is another fluctuation that occurs annually. The climatic conditions at the cessation of the early rains would appear very suitable for the recovery of the fly community.

During the heavy rains, March and April, one also finds constant fly behaviour, the numbers indicating a medium high density, somewhat lower than that of February. Thus one can say that for three-quarters of the year, namely from August until April inclusive, the same seasonal fluctuations in fly density occur every year, without fail. During this period breeding, as indicated by the freshly emerged fly curve, can be said to decrease as the dry season conditions become more severe, until it is almost at a standstill. It accelerates after the advent of the early rains, producing a great burst of emergence in late January and February. Throughout the heavy rains breeding is relatively low. It can also be said that during three-quarters of the year the same seasonal fluctuations in breeding occur annually.

May, June and July are the months that compose the inconstant quarter of the year. The fluctuations in fly density for this period, which follows the heavy rains, depend upon the rainfall.

In dry years, such as 1928 and 1929, a great burst of emergence takes place at the end of the rains, and throughout May there is an increase in fly density. In 1929 when the rains were very poor and there was famine in some districts, this increase in fly numbers was very marked.

These dry years are characterised by the severity of the cold spell that occurs in June, July or August. The mornings are bright and crisp, and near dawn it becomes very cold. In early August 1929 when an ecological investigation was carried out in Kikori under Dr. Phillips, the mean minimum screen temperature in an "mbuga" from 9th to 14th August was 41°F., the lowest reading being 39.25°F. For the same period readings taken in the *Berlinia* wooding, or true habitat, gave a mean minimum of only 45°F., the lowest reading being 43°F. Such low temperatures definitely affect the fly community. Newstead (1924) records that Fisher, writing in 1913, stated that the death rate of *G. palpalis* in the laboratory was especially high on several nights in July when the temperature went down to 6°C. (43°F.).

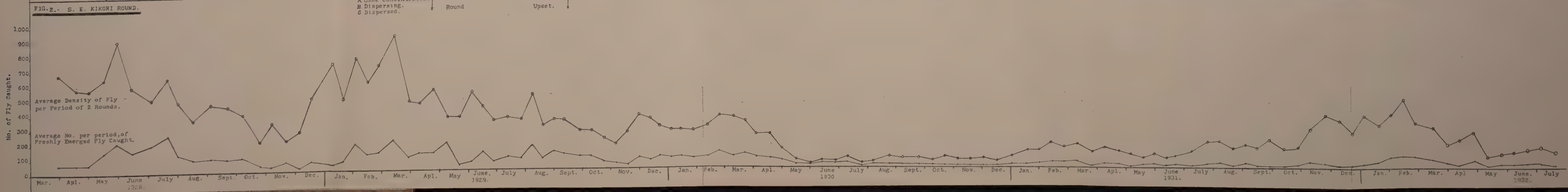
The high densities found at the end of the heavy rains continue until the advent of the cold spell. In 1928 the high density was of short duration as the cold spell was in late June and early July. Note how the total fly numbers decreased, and yet the numbers of young fly remained very high. At the end of the cold spell the fly density rose for a short while, prior to the drop that always occurs in the late dry season. In 1929 the cold spell came in early August, consequently there was a long period of high fly density in May, June and July. The cold was so late this year that the fires followed almost immediately afterwards, preventing any recovery after the cold spell. Unlike 1928 the reduction in numbers due to cold and fires forms an almost continuous drop.

Note again how the freshly emerged fly numbers remain up, despite the drop in total fly density. This is an important point as it suggests that the cold affects the total density through killing off the old fly, leaving the freshly emerged individuals unharmed. If anything, the cold stimulates emergence.

We have now dealt with the fluctuations that occur after years of scanty rainfall. In years of heavy rainfall, should much rain be precipitated towards the end of April and early May, one finds that fly give quite a different reaction. Instead of a rise in fly density at the end of the heavy rains one finds a drop, the extent of which depends upon the amount of rain that fell during this critical period. In 1930 the drop was considerable, reaching a minimum point in late May; in 1931 the drop was less striking and reached its minimal point in early June.

In these wet years the cold spell occurs, but its intensity is not sufficient to affect the fly. Owing to the humid conditions prevailing at the end of the rains, heavy clouds hang over the escarpment and cold, crisp, sunny mornings are rarely experienced, with the result that very low minimum temperatures are never registered. Mean monthly temperatures are misleading, because they show lower temperatures in these wet years owing to the overcast days, and resulting low maximum readings. In dry years the very cold minimum readings are masked by the relatively high maximum temperatures that follow the sunny mornings.

The great drop in fly density occurring at the end of the rains in 1930 is considered to have been due mainly to the destruction of the tsetse, in the puparial stage, that were waiting for the rains to end before starting to emerge. The relatively small drop in 1931 may be partly due to destruction of puparia, but the effect could be produced by lack of sunshine and high humidity alone. Such conditions might reduce the fly activity to such an extent that many individuals would die of starvation. The writer wishes to stress the point that total rainfall means nothing. It is the distribution of the rain that affects the tsetse community. The fly appears to be able to withstand the normal heavy rains of March and April, but if in late April and May when the rains should be almost over, there is continuous heavy rain, as in 1930, then the community





is seriously affected. The puparia that are waiting to produce the great burst of emergence at the end of the rains are either killed by submergence, or the young fly emerge into an unfavourable, sunless, humid environment, that they cannot withstand.

It would be quite possible to have a year showing an abnormally heavy total rainfall figure, and yet an unaffected fly community. Let us take an extreme case: — One might have four inches precipitation once a week only, and hot sunshine on the intervening days; the water would then soon dry up, and after two or three days conditions would again be favourable to fly. In such a year the fly community would be quite unaffected. The soil would never remain water-logged for long, and very high humidities would be of short duration only. Hence the puparia would not be destroyed by over four days submergence, and the adults would not suffer from fungus or lack of sunny hours for feeding. The period of the heavy rains of 1932 is an excellent example of the case just cited.

During the biological year 1929–1930, when the fly were so nearly exterminated in May 1930, the total rainfall was 51 inches (Table IV), whereas in 1931–32 the total was 48 inches; yet in this latter year the fly, though conforming to the wet April type of fluctuation, were in no danger of destruction at the end of the rains. Though the total rainfall figures are so similar, yet in 1929–30 the rainfall was badly distributed, there being an aggregation of wet days in April and May, whereas in 1931–32 the precipitation was well distributed. A glance at the evaporation statistics (Table V) will confirm this statement: it will be noticed that for April 1930 the evaporative power of the air was exceedingly low, whereas for the same month in 1932 it was relatively high. It is the aggregation of wet days at a critical period in the fly's annual cycle that upsets the tsetse community.

Having dealt with the typical annual cycle in variations of fly density, as shown by the N.E. Kikori round, the writer will now deal with the exceptions that occur on the remaining two fly-rounds.

The S.E. Kikori Round (fig. 2).

Throughout 1928 the fluctuations are typical.

In 1929 the rise in fly density did not reach its maximum in February, the short dry season, but in March after the rains had broken. This was caused by a game concentration on the round due to water shortage, the season being exceptionally severe. Game concentration is believed to have resulted in fly concentration within the area tapped by the round. It was not until the rains broke that the game dispersed, thus freeing the attentions of the fly concentration. Those individuals that had gorged upon the game just before the rain broke found that the game had left when they became active some days later, and so appeared to the catchers in large numbers. It took some time for the fly concentration to disperse completely through hungry tsetse roving further and further in their search for the missing food supply.

From late April until mid-September 1929 the graph can be ignored, as the area was completely upset by human activities. At this time lorries were driven through that part of the bush that formed the core of the round, and large gangs of natives were also employed. The fly-round path encircled this area, and possibly the absence of a great increase in fly density in May and June may have been due to the fly having all been attracted into the centre, where the human bait was concentrated. This period is of no scientific value except as showing the effect of human activities upon masking the seasonal fluctuations.

For the rest of 1929, and throughout 1930, the graph behaves according to type. Note how very scarce fly were after the torrential rains of 1930. Throughout 1931 we witness the gradual recovery of the fly community. Numbers are too small to demonstrate the seasonal fluctuations, however the February peak is discernible, and the drop that follows a wet April and May.

The great trough in the fly density curve that is a characteristic of the late dry season is not represented, owing to a game concentration on the round, which produced a concentration of fly from the surrounding areas. Hence the appearance of an increasing density in November which is a month before its time. It will be remembered that normally density is low in November when the early rains break, and that it does not start to rise until December. Here, however, the breaking of the rains enabled the game to disperse, and consequently freed the attentions of the fly. The drop of the fly density curve as the fly concentration dispersed is checked in mid-December by the true seasonal rise in fly density. Early 1932 is true to type, the February peak occurring as usual, as well as the drop after the rains, which is in accordance with a wet April.

The S.E. Kandaga Round (fig. 3).

Owing to lack of staff the writer was only able to carry out this round for six months in 1928. The figures are dangerously small; however, a slight rise at the end of the rains, with a drop for the cold spell and subsequent recovery are discernible points. The absence of a pronounced decrease in density in September and October is probably accounted for by the fact that Kandaga was not burnt, whereas Kikori was burnt in early September. Naturally when the country is burnt it is much more inhospitable to fly owing to lack of shade, radiation from the black ground, and increased evaporation.

The round was continued in early 1929, and agrees with the type in the great increase in fly density following upon poor rains, and the subsequent drop during the cold spell. It was not intended to burn this round in 1929, but unfortunately very poor patchy fires did occur. Even so, it is very noticeable how different are the results obtained if normal fierce fires are excluded.

No great decrease in fly density occurred in late October and November as on the other two rounds which were normally burnt. The patchy burns produced a temporary effect some little time later. There was a burst of emergence from late November until the end of December, and fly density was high throughout this period. From the end of December until mid-March 1930 there was a very gradual but steady drop in fly density and the numbers of freshly emerged fly. From mid-March until mid-April the fly density remained steady at the same medium level as in 1928. Then came the late April downpour and the same dramatic drop in density that occurred upon the other rounds.

A comparison of this almost unburnt round with the two well-burnt Kikori rounds is of great interest. At Kandaga the density was highest in late November, whilst it was lowest at Kikori. Then whilst the fly density at Kikori was slowly climbing to the February peak, the density at Kandaga was slowly dropping, until it steadied in mid-March.

Throughout this period the great difference between the two places was as follows :—

At Kikori, as the early rains progressed, the burnt and shadeless ground gradually gave way to the new grass, which is attractive to game, and gives more shade and concealment to the tsetse.

At Kandaga the old, unburnt grass got thicker and thicker as it was reinforced by the new growth, and the visibility became worse. Game became scarcer and hunting more difficult for the tsetse.

Hence throughout this period the fly's environment at Kikori was steadily becoming more and more attractive, so fly density increased. At Kandaga the environment became steadily worse, and so fly density decreased. Equilibrium was reached in March when the heavy rains started, as by that time the grass was long both at Kikori and Kandaga, and, as usual, game was scattered all over the country.

From the figures it would appear that whether one has effective fires or whether they are held up for the year the fly density is adversely affected, but eventually the results are the same (March and April). If there are fires, the density falls after them and later recovers; if there are not, the density remains high, but later falls.

Hence in one year of partial fire control, the results are eventually the same. It is interesting to speculate what the results would be were an area preserved from fire for three or four years. This is being done by the Tsetse Research Department in Shinyanga. The absence of a good burn on the Kandaga round in 1929 should be looked upon as an artificial abnormality. The fires are as much a part of the normal season in Tanganyika Territory as are the rains.

Continuing with this round :—The great decrease in fly density that followed the torrential rain of April 1930 is most marked. The gradual struggle for recovery is in agreement with other rounds. Here, as with the S.E. Kikori round, density rose in September, October and November, when fly is normally scarcest. The explanation is similar. Game concentrated at this time, and did not disperse till mid-November. The fly, no longer absorbed in the game, attacked man with vigour, causing a small peak in late December. The fly concentration dispersed, and density dropped slightly at the end of December, but a further decrease was averted by the natural seasonal increase in density that had started, and which reached a climax as usual in the short dry season (February). Density, though fluctuating, remained fairly high throughout the heavy rains, after which it tended to fall in accordance with the wet April type of fluctuation.

* * * *

It will be clear after this review of the fly-rounds, that seasonal fluctuations in fly density are most clearly followed on the N.E. Kikori round, where the seasonal factor is not concealed and distorted by the game factor. At the same time it is apparent that the S.E. Kikori round agrees with the N.E. round, except when the seasonal fluctuations are masked by game concentrations. Before the early and heavy rains there may be water shortage in the plains; this drives large herds of game in from the Masai Steppe to water at the foot of the escarpment in the area tapped by the S.E. Kikori round. Clearly, if the true seasonal fluctuations of a tsetse community are under study, it is essential to choose an area where game is not migratory, otherwise false and conflicting results may be obtained. The value of the Kandaga round is that, unless artificially tampered with, it supports the results obtained at Kikori which is twenty miles further north.

Conclusions.

1. From August until April the density of the fly community follows an annual cycle which is constant from year to year.
2. From May to July is a critical period in the existence of the tsetse population. In dry years they flourish, but should there be an aggregation in the number of wet days in late April and May, the community may be faced with partial extermination or at least a reduction in numbers.
3. Game concentration can mask the seasonal fluctuations of fly density.
4. Human activities in the area being studied can upset the results completely.
5. The suppression of the seasonal bush fires is at first favourable to the community but later adverse.

3. The Meteorological Factors influencing the Seasonal Fluctuation in Density.

So far it has been shown that the fly density varies according to season. No explanation has been given for the annual cycle that is constant for three-quarters of

a year; only the irregular three months succeeding the heavy rains have been dealt with. It has long been realised that certain meteorological factors influence certain stages in the development of the fly.

Temperature.

Temperature has been correlated with certain stages in the development and in parts of the annual cycle of *G. morsitans*. For instance it is well known that the duration of the pupal period in *Glossina* varies as the temperature; low temperature, long pupal period; high temperature, short pupal period—Bruce (1915), Lamborn (1916), Lloyd (1912 and 1914), Chorley (1929 b), Harris (1930).

Temperature has been shown to produce a reduction in fly density during the cold spell (see p. 118). Roubaud (1909 a) states that *G. palpalis* can only reproduce between temperatures of 77°F. and 86°F. Jack (1927) states that 79°F. is the optimum mean annual temperature for *G. morsitans*; the mean annual temperature at Kikori for 1929 when fly was most abundant was only 70°F.

Hence, though temperature undoubtedly does play a most important part in the development of the fly and in its activity, one cannot isolate it as being the factor of greatest importance.

Precipitation and Humidity.

Most workers have been inclined to place rainfall and humidity as the most vital factors in the life of the tsetse; e.g., Simpson (1918). Roubaud (1909 b) showed that *G. palpalis* reproduces normally at 70% relative humidity, but that 100% humidity will arrest reproduction. The writer has just shown that the fly density at the end of the heavy rains depends upon the distribution of rainfall at this time.

* * * *

Many similar, disconnected observations have been made by different authors, indicating that temperature, humidity, rainfall and wind, are all important in the bionomics of the tsetse, though no one factor can be isolated as being of more value than another. Owing to the obvious importance of each factor, the writer has concentrated upon studying the effect of the evaporative power of the air, because this factor is influenced by all the other factors.

Evaporation.

"The evaporative power of the air is the result of several separate factors, viz., temperature, relative humidity, air movement and barometric pressure" (Uvarov, 1931). It was felt that a factor influenced by so many other important factors should repay attention. Hence the seasonal variations in the evaporative power of the air were compared with the variations in fly density as given by the N.E. Kikori round. It was found that an apparent correlation existed when the mean monthly evaporation was plotted against the mean monthly fly density of this round. These preliminary results were published in a very short paper (Nash, 1931). For three years this apparent correlation has continued.

The subject has been dealt with biologically by the writer, and will be treated in this fashion hereafter. At the same time it is clearly a subject of great statistical interest, as has been pointed out to the writer by Dr. P. A. Buxton, of the London School of Hygiene and Tropical Medicine.

The available data were sent to Dr. Buxton, and Miss Woods of the same institution very kindly examined them. The results, so far as they went, were satisfactory and bore out the conclusions that have been reached. The whole subject will be gone

into statistically on the writer's next visit to England, and consequently the subject will be dealt with from a statistical point of view in some future publication.

At the same time the subject cannot be ignored, as it is of vital importance to the theme of this paper.

* * * *

Fig. 4 shows the seasonal variations in fly density and evaporation. Monthly means have been used, so that the fly figures can be based upon large numbers. If weekly evaporation and fly caught at ten day intervals be used, the results are similar but a less even curve is obtained.

In June and July 1929, the fly density was at its maximum. Hence it is reasonable to suppose that at this time the evaporation was suited to the requirements of the tsetse community.

Let it be assumed that a mean monthly evaporation of from 20 to 25 ccs. a day affords an optimum condition for fly. It will be seen that as the evaporation increased above this figure, so the fly density decreased. At the end of the dry season, October 1929, the evaporation reached its maximum of an average of 60 ccs. a day. Hence this month may be considered to have afforded the worst conditions for the fly community.

One would hardly expect this adverse factor to have an immediate effect upon the tsetse; however, by the next month the fly density had reached a minimum. The early rains now broke, the evaporation fell with the moister atmospheric conditions, and fly density started to rise in the following month (December).

By January 1930 the evaporation had dropped to within the alleged optimum zone, 20-25 ccs. a day. Yet again, after a month's lag the fly density reached its second maximum point.

So far the correlation has been negative; as one goes up the other goes down.

It has been suggested that if the evaporation reaches an extremely high figure, its effects will be inimical to fly (*vide* October 1929); similarly, it is suggested that if the evaporation falls below a certain point, it may also produce conditions adverse to fly.

As already mentioned the rains of 1930 were abnormally heavy. It will be seen from the graph that in April the mean daily evaporation was about 7 ccs. a day, and that after the lag of a month the fly density fell considerably. It must be realised that this drop was somewhat indirectly caused by evaporation, as it is believed that the destruction of puparia due to submergence was the chief factor. Here the low evaporation is an indicator of the nature of the destructive factor, and is not the factor itself.

After this, the evaporation rose until it reached the alleged optimum zone for fly in July and August 1930. In August the fly reached its third maximum point. The evaporation then steadily rose above the 20-25 ccs. mark, and as in 1929, the fly density steadily decreased. Lack of space prevents further description of the courses followed by these two curves throughout the ensuing years, but it will be seen that their behaviour continues similar to that already described.

It has been suggested that a month after the evaporation has passed through the optimum zone fly density is maximal, and that tsetse decrease in numbers when evaporation is either greater or less than 20-25 ccs. a day. In other words, the correlation is believed to be "skew," since it may be negative over one part of the range and positive over another.

It is clear that a lag exists. From a large scale graph the lag would appear to vary from two to five weeks. Hence in fig. 4 some of the apparent disagreements are due to the fact that evaporation is only plotted by months. For instance there is an

apparent disagreement in February. In 1931 and 1932 the mean monthly evaporations for January and February were almost identical. Yet fly density rose in February for the January evaporation, and dropped in March for the February evaporation. In other words, fly density behaved differently for approximately the same evaporations.

The explanation is simple:—There was rain and consequent low evaporation in early and late February in both years, but in mid-February it was exceedingly hot and dry, and the evaporation for this fortnight rose considerably. This temporary return to high evaporations is believed to have caused a drop in fly density in the March of each year; but these high evaporations are masked in the mean monthly figure by the low evaporations of the first and last weeks.

Similarly the evaporation appears to have reached its maximum in November, and yet fly density has risen considerably in December, instead of falling further. The first part of November was very hot and dry, but the rains broke in the middle of the month; hence the evaporation really dropped very considerably towards the optimum zone during the last fortnight of November, and thus caused an increase of fly in December. The mean monthly evaporation figure for November masks this fact.

For this reason the weekly evaporation figures have been plotted as points in these months where there are apparent disagreements. Another source of apparent discrepancies is the lack of activity of tsetse on certain days during the heavy rains. A fly-round may be carried out on a day when there is much rain, and hence the total fly caught does not afford a true index of fly density. It is essential to take into consideration these obvious sources of error, and not to be too critical of the occasional disagreements.

In the section dealing with seasonal fluctuations it was shown that for three-quarters of a year the fly community passed through a constant annual cycle, which was broken in April, after which one of two things might happen, according to the rainfall distribution. It will now be shown in still more convincing fashion that this annual cycle is dependent upon the evaporation. Should one make a graph having the ordinate serving for the evaporation, and the left abscissa for the fly density, and should one then plot mean monthly fly figures against the mean monthly evaporation of the previous month, one might expect to find all high fly densities occurring in the optimum zone, and the density dropping as the evaporation recedes from each side of this zone. Such a graph is given in fig. 5, and it will be seen that the result is as expected.

Each point represents the fly of the month in question and the evaporation of the previous month. The month and its year is written against each point. The points have been joined in monthly order. Each annual cycle falls naturally into a dry season and a wet season cycle.

The graph does not extend beyond November 1931, because it was felt that the addition of any further cycles would obscure the picture. This division of the annual cycle into two is not arbitrary. Each year the dry season cycle comes to a natural conclusion with the break of the early rains in November, after which the evaporation ceases to rise and the fly density to fall. After November the evaporation starts to fall and the density to rise. It may simplify matters to describe the cycles.

1929. Dry Season Cycle.

In July 1929 fly density was very high, because June's evaporation was almost in the optimum zone. As the evaporation rose through the long dry season, so fly density fell. The minor cycle ends with minimum fly in November, due to maximum evaporation in October. The rains broke in early November.

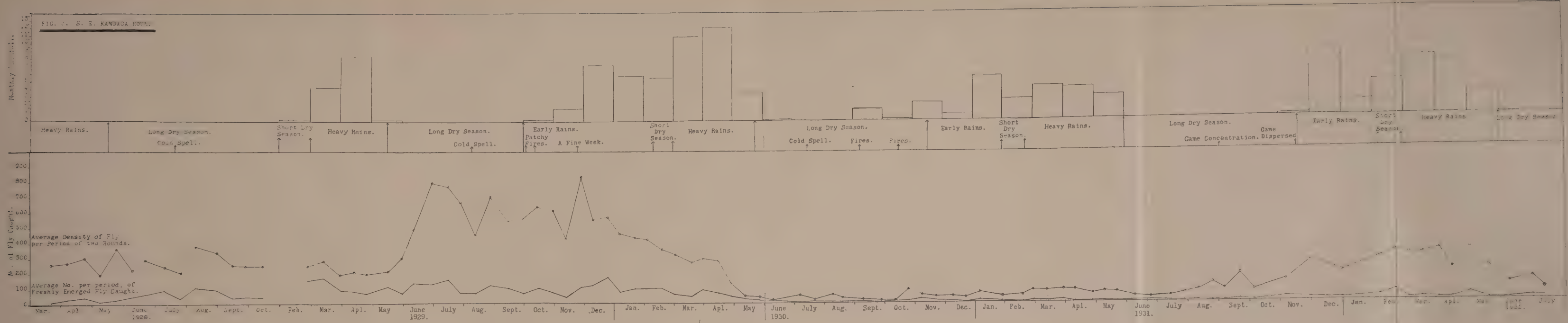
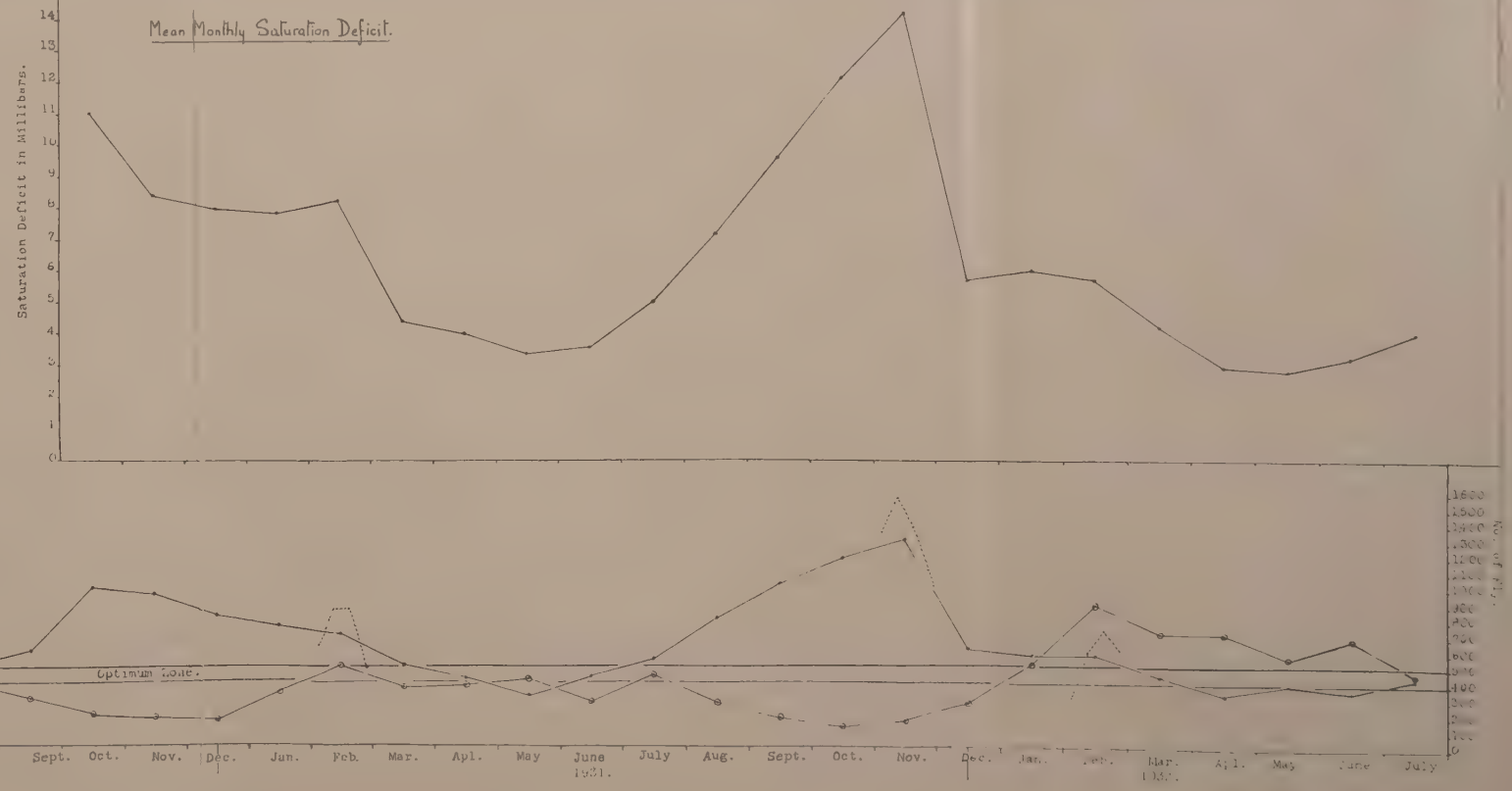


Fig. 4.
N.E. KIKORI ROUND.

A Comparison between the Mean Monthly Evaporation
and the Mean Monthly Fly Density.



1929-1930. Wet Season Cycle.

As the early rains continue, so the evaporation drops, and returns towards the optimum zone; hence the fly density rises, and reaches its maximum in February because January's evaporation had been optimum. Conditions now become too humid, this being the year of the torrential rains. Evaporation drops below the optimum and so fly density decreases. Note the tremendous drop in May due to the April downpour.

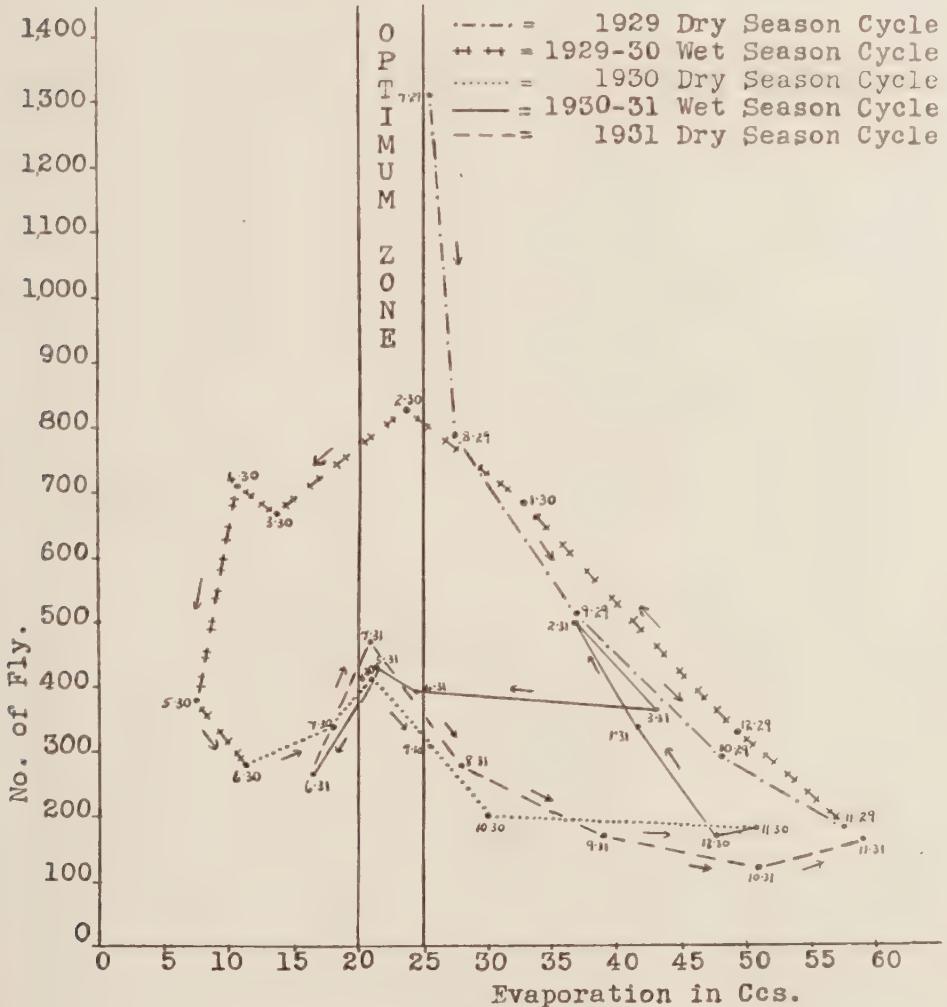


Fig. 5. Fly plotted against the evaporation of the *previous* month. Months refer to the month when fly were caught; *not* the month of the evaporation.

1930. Dry Season Cycle.

As the bush dries up in June, the evaporation returns towards the optimum, and fly density rises, reaching its maximum in August. Compare this maximum point of fly density for this year's cycle with that of the previous year in July 1929. It

dramatically shows the magnitude of the calamity that overwhelmed the tsetse community. With the onset of the dry season the evaporation only stayed in the optimum zone for a month. Soon the evaporation was rapidly rising and the fly density falling.

Note that this year, owing to the saturated conditions that occurred at the end of the rains, the bush was slower in drying up and therefore the maximum evaporation was less than usual. Consequently fly density did not drop so low as in the following year. The early rains broke in November.

1930-1931. Wet Season Cycle.

As the rains gained force, so the evaporation started to return towards the optimum, and fly density rose. This year the short dry season of mid-February was very severe. The return of the evaporation to the optimum zone was sharply checked, the evaporation rising, instead of continuing to fall as in the previous February. The severity of this check was sufficient to cause a drop in fly density in March 1931. (As the mean *monthly* evaporation figure would have masked this important fact (see p. 124), the evaporation for this middle fortnight of February has been incorporated in the March point on the graph.) This check occurs in every year in which the short dry season produces severe conditions.

Continuing, the fly density made a poor recovery in May when a maximum point was reached. It seems likely that had there been no short dry season check, a high maximum point would have been reached as in 1930. Fly density dropped in June owing to the evaporation having fallen below the optimum in May, and this was due to the unusually late and evenly distributed rainfall.

1931. Dry Season Cycle.

Evaporation returned to the optimum zone and fly density reached a maximum in July. The bush rapidly dried up, the evaporation rose above the optimum zone, and fly density fell as usual.

* * * *

It will have been noticed that fly density always reaches a maximum point for its cycle in the optimum zone, owing to the fact that the previous month's evaporation has fallen between the 20-25 ccs. mark. Broadly speaking, one can say that the erratic quarter of a year, which includes the latter part of the heavy rains and the months immediately following, falls on the left of the optimum zone. In this area fly density drops as evaporation drops below this zone, whereas on the right-hand side, fly density drops as the evaporation rises. The correlation is positive on the left, and negative on the right. Rises in fly density converge on the optimum zone from each side. Fig. 6 shows an almost similarly constructed graph in which fly density has been plotted against the evaporation of the *same* month. Note the lack of correlation; the maximum fly density points occur all over the graph and are not confined to the optimum zone. This is a very vital point. Had there been correlation between fly density and evaporation of the *same* month, one would have expected that evaporation would have affected fly activity. One would then have suspected that the fly-rounds did not give a true index to fluctuations in fly *density*, but that they merely indicated variations in fly activity, brought about by the effect of evaporation at the time of the catch. Obviously the evaporation of last month cannot affect the activity of fly this month. The effect must be deeper, such as an effect upon the breeding or longevity of the fly community.

Unfortunately it has not been possible to prove what the effect is; but there is a certain amount of indirect evidence that tends towards the hypothesis that evaporation affects the longevity of fly. From the fertilisation of the parent to the emergence of the young fly occupies 43-66 days in this district. From June until August

the period is about 66 days, hence the effect of favourable evaporation upon stimulating copulation at this time of year would not produce an increase in fly for over two months. The lag is believed to vary between two and five weeks, and when taken as a month gives good results on the graphs.

If favourable evaporation affected breeding, one would expect to find no correlation on the graphs between June and August; however, there is an obvious correlation. Evaporation might affect the emergence of fly from their puparia, but since the latter are often buried underneath an inch of soil this is hardly likely.

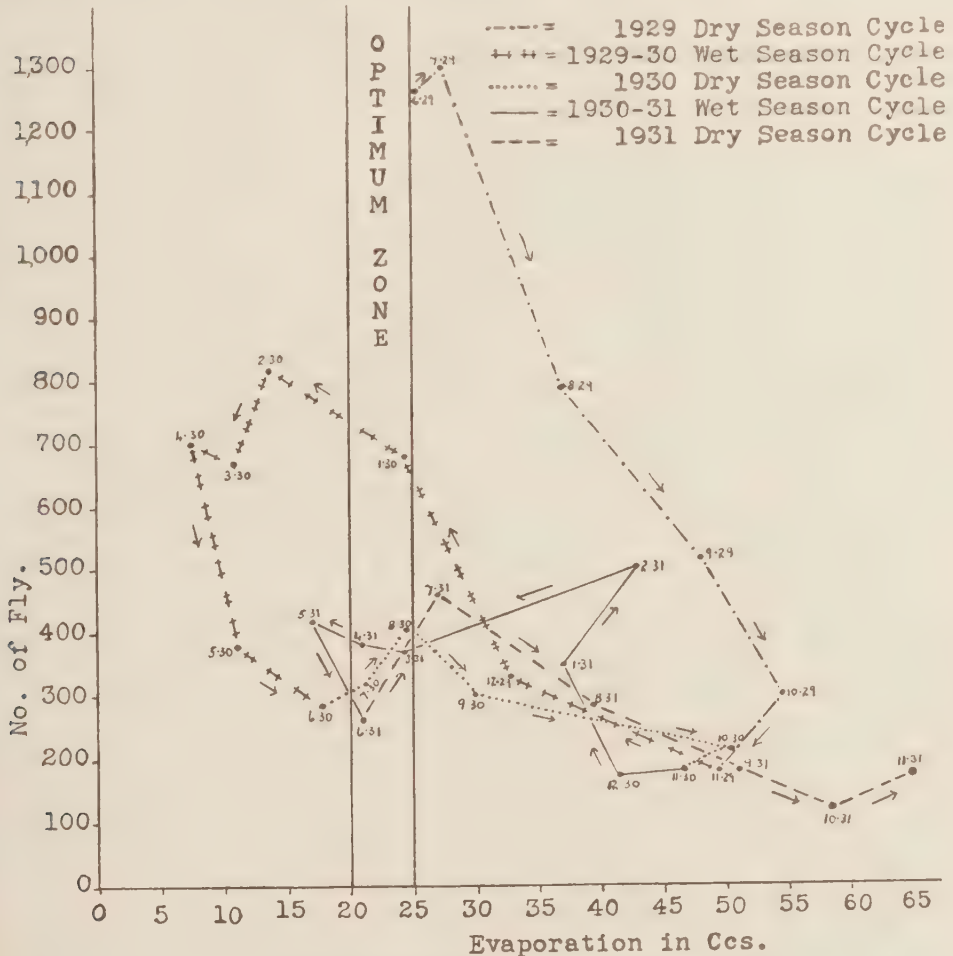


Fig. 6. Fly plotted against the evaporation of the same month.

The most probable explanation is that evaporation affects the longevity of the fly. When evaporation is favourable fly would live longer, and since the emergence of fresh individuals is constantly taking place, it would not be long before an aggregation of tsetse resulted, and consequently an increase in fly density.

Should the evaporation be unfavourable, the longevity of fly would be decreased, and consequently females would extrude fewer larvae. The result would be a decrease in fly density, because, apart from the short duration of the adult's life, there would

not be much emergence to replace the constant deaths occurring in the community. It should be remembered from the fly-round graphs that young fly are scarcest at the end of the long dry season and in the middle of the heavy rains.

There is a certain amount of evidence to show that evaporation does affect the adult fly. Dr. Jackson, of this Department, has recently been finding that high evaporation increases the hunger of *G. morsitans*. He has found that during the rigours of the late dry season tsetse become hungry in half the time needed during the rains. He consequently believes that tsetse "live quicker" at the time when evaporation is very high.

The finding of food must always be the tsetse's most pressing problem; hence it is a very serious matter for the fly to require food so often during the severe climatic conditions that are found after the bush fires. Constant searching for a host must rapidly expend the energy of a tsetse.

Not very much laboratory work has been done upon the subject of the relation of the longevity of fly to the humidity of the atmosphere. Roubaud (1909 b) found that the longevity of adult *G. palpalis* in saturated air is six times that in normal air and twelve times greater than in dry air.

These results satisfactorily explain the decrease in fly numbers during the later dry season, but make one wonder what *direct* effect, if any, high evaporation has upon *G. morsitans* at the end of the heavy rains. It must be remembered that Roubaud was working upon *G. palpalis*, a species that owing to its dependence upon water in its environment would be far more tolerant of low evaporation, and more intolerant of high evaporation than *G. morsitans*. Thus it is possible that *G. morsitans* cannot withstand a saturated atmosphere, whereas *G. palpalis* thrives in it. When evaporation falls below the optimum zone, it may really cause a subsequent fall in fly density, by reducing the adult's longevity, or it may merely be an indicator of the inundation of the puparia, or the lack of sunshine and consequent harmful reduction in fly activity. It will have been noticed that the alleged optimum zone occurs when humidity is fairly high. This is to be expected because higher humidities are favourable to insects as they render the insect less susceptible to heat (Uvarov, 1931).

The cessation of extremely arid conditions with the advent of the early rains, and the subsequent rise in fly density, may be due to the more humid conditions which reduce the fly's susceptibility to the high temperatures that occur at this time of year. Uvarov (1931) concludes that "the influence of external temperature on the activities of insects is not direct, but acts through their body temperature." Shelford (1914) stresses the importance of evaporation, and of all factors influencing its rate, upon the body temperature of insects.

Hence unfavourable evaporation may reduce the longevity of *G. morsitans* through upsetting its body temperature, and at high evaporations through making it expend more energy in search of food.

An interesting point is that the fly density fluctuations can also be correlated with the saturation deficit of the atmosphere. This is only to be expected, as this unit also depends upon the combination of temperature and humidity. The practical value of this point is that if one has no atmometer, but has a recording thermohygrograph one can also study the correlation existing between fly density and the temperature and humidity factors combined.

The discovery of the connection existing between fly density and evaporation has been of great practical value to the writer. Knowing the evaporation of the last month he has been able to predict whether fly are likely to increase or decrease in numbers during the coming month. In arranging the dates for experiments or for the liberation of parasites, it is of value to know whether tsetse will be abundant in the near future.

A comparison between fluctuations in fly density and evaporation for the S.E. Kikori round gives poor results. The writer believes that a correlation exists during certain parts of the year, when game concentrations did not occur. Naturally the concentration of fly from areas outside the fly-round may give an impression of increased fly density, when fly are really becoming scarcer. Thus towards the end of the long dry season, when the evaporation is rising, migratory game will concentrate within the fly-round bringing tsetse with them. This produces the effect of increased fly density, at a time when fly should be becoming scarcer. Naturally this sort of thing entirely masks any correlation that might exist.

For an investigation of the type described it is essential to choose an area where fly is abundant and the food supply non-migratory. The fly-round should pass through the centre of well-watered country and not on its edge, where game from outlying arid regions may be forced to concentrate seasonally. Again the investigation should be confined to the true habitat of the fly, where breeding is abundant throughout the year. Areas from which the fly migrate during the rigours of the dry season are obviously unsuited.

The N.E. Kikori round meets with all the above requirements. The catch is made within the true habitat and within the fee ling-grounds that fringe it. The S.E. Kikori round is situated in the plains and certain sections become almost devoid of fly at the time when the tsetse tends to concentrate within its true habitats. A possible criticism of the work described is that the effect of high evaporation is not to reduce the fly density but to make the fly migrate to another district. Fortunately this is impossible, as this small fly-belt is hemmed in on all sides by natural barriers as described in the introduction. The enclosed area is thoroughly tapped by the 26 miles of fly-round, and the writer is confident that no mass migration of the fly community to one corner of the fly-belt could take place without his knowing it. Certain small-scale migrations of fly from temporary wet season habitats to the true habitats are known to occur, and will be described later.

Conclusions.

1. The seasonal fluctuations in fly density can be correlated with fluctuations in the evaporative power of the air.

2. There is a lag of from two to five weeks in the effect of a fluctuation of the evaporation upon the density of *G. morsitans*.

3. A mean monthly evaporation of 20-25 ccs. a day affords optimum conditions for fly, and results in a maximum density in the following month.

4. As the evaporation rises above, or falls below, this alleged optimum zone, so tsetse decrease in numbers. As evaporation returns towards the optimum zone, so fly density increases.

5. Evaporation is believed to affect the adult fly by increasing or decreasing its longevity. It does not affect the fly density, as apparent to man, by affecting the fly activity at the time of catching.

II. ECOLOGY OF *GLOSSINA MORSITANS*.

The first section of this paper dealt with fly-rounds and their results. This type of fly survey was originally instigated with a view to obtaining information upon the ecology of *G. morsitans*. It has been found, however, that there are certain gaps in this information which have had to be filled by results obtained by specially devised experiments. The next section consists of a summary of the knowledge obtained in the first one together with these special experiments and their results. The matter contained in this part has been grouped under the three great factors—season, game and vegetation—which play such a vital part in the ecology of the tsetse. The summary for this part is written in the form of a concept of a fly community as based upon the results already given.

1. The Seasonal Factor.

Fly density and season.

The seasons will be dealt with separately as follows:—

Late dry season (September and October).—The evaporation rises and fly density steadily falls.

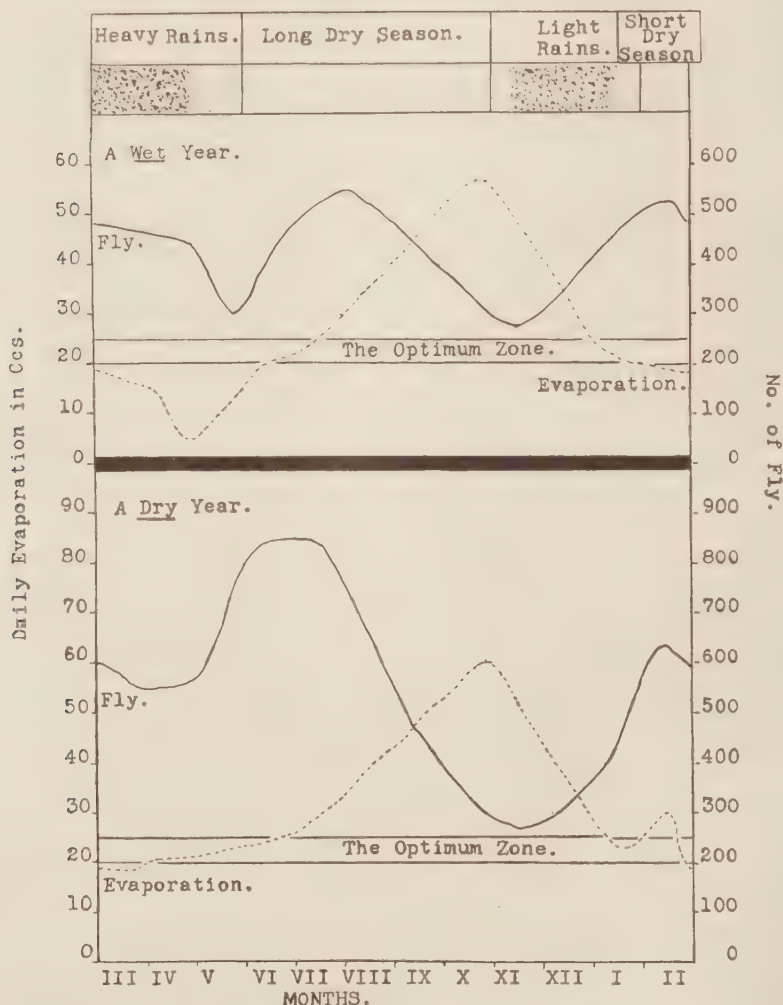


Fig. 7. The effect of season upon *G. morsitans* as epitomised by the evaporative power of the air.

Early rains (November–January inclusive).—Density remains throughout November at the same minimal point that it reached in October. Throughout December and January density steadily rises, owing to the fall in the evaporation.

Short dry season (February).—Fly density reaches a maximum point during this month.

Heavy rains (March and April).—Fly density falls slightly, owing to the temporary rise in evaporation during February. Density then remains at a steady medium high level.

Early dry season (May–August inclusive).—(1) After poor rains. A great increase in fly density takes place in May at the end of the rains, a maximum being reached in June. About July the cold spell causes a drop in fly numbers. Fly density recovers at the end of the cold spell, but before long starts to fall towards the late dry season minimal point. (2) After very heavy rains, and a very wet April. In early May the fly density is steadily falling. It reaches a minimum point in late May or June. As the country dries up the density rises, reaching a relatively high figure in August, after which it starts to drop towards the late dry season minimal point.

Fig. 7 is a diagram designed to demonstrate as plainly as possible the nature of the seasonal cycles in fly density and evaporation.

It will be noticed that in a wet year fly numbers are never so great as in a dry year, owing to the fact that the evaporation never remains within the optimum zone for long. In dry years the "heavy rains" are finishing in April and the evaporation lingers within the zone for a considerable time, resulting in great fly density in June. In wet years the evaporation falls considerably below the optimum.

Effect of season upon breeding.

The following results have been obtained by studying the numbers of young fly and the freshly emerged fly percentages taken from the fly-round data; in addition collections of puparia from fixed sites have aided the writer in coming to the following conclusions.

Emergence of young fly from their puparia is least at the end of the long dry season and beginning of the early rains (October and November). Emergence is greatest at the end of the early rains and throughout the short dry season (January and February). Throughout the heavy rains but little emergence takes place (March and April). In dry years there is much emergence at the end of the heavy rains (May to July), but this does not occur after very wet years.

Generalising, one can say that breeding is greatest when the evaporation curve approaches the vicinity of the optimum zone.

Comparison with the results of other workers.

The literature upon the seasonal variations in fly density is very scanty. Much of the existing knowledge is unsatisfactory owing to the short-period observations upon which it is based. It is clear from these results that any conclusions based upon too short a period are likely to be of little value. The writer himself fell into this error when he published results upon this subject in 1930, after only one and-a-half years' observation. He gave a hypothetical graph of the normal seasonal variations in density and breeding. In view of more recent work, it is clear that this graph, though perfectly correct for dry years, is incorrect for years in which April and May are very wet. It happened that the first two years of observation were exceptionally dry, though at that time they were thought to be normal.

Ensor (1909) states that in the Sudan fly are most numerous soon after the rains, and least after the grass fires. Tsetse greatly increase at the end of the rains according to Simpson on the Gold Coast (1918). Chorley in Southern Rhodesia (1929 a) says that *G. morsitans* greatly decreases in numbers in the mopane forest after leaf-fall.

Hence there would appear to be agreement with these authors that fly density is low at the end of the dry season after the fires, and also that fly density increases at the end of the rains, though this increase only takes place at Kikori after dry years. On the other hand Chorley also states that fly density is greatest in September towards the end of the dry season, so possibly the decrease he refers to only occurs in the mopane forest.

Much of the confusion upon this subject is due to the fact that the migration of fly and seasonal variations in density are taken as being almost one and the same thing. Newstead (1924) states that "the subjects *Migration of Fly* and *Seasonal Variation* are very much bound up together."

The writer believes that the subjects should be dealt with separately. *G. morsitans* varies in numbers according to the season, as has been shown. It also varies in distribution according to season, as will be mentioned later.

If a certain area of savannah bush is evacuated in the dry season, owing to fly having concentrated in the true habitat, it does not mean that the habitat has its original population plus the open savannah population, and that therefore the total fly density for both areas combined is as great as before the evacuation. On the contrary, a study of two such adjacent pieces of bush will show that the density in a large strip of the habitat has decreased, but that the density in the open savannah has decreased infinitely more. Mere observation will show that whereas the open savannah used to support a large population during the wet season, in the dry season it is practically evacuated, there being a large concentration of fly in the surrounding fringe of the true habitat. One thus erroneously concludes that the savannah fly have now swelled the numbers in the true habitat, and that hence the total population of the two combined has not altered.

Careful study of fly numbers shows that despite the concentration, fly density over a large area is decreasing owing to the rigours of the dry season. The fly density of the whole tsetse community decreases towards the end of the dry season, though at this time certain small areas may increase in their local fly density owing to a concentration of fly within them.

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The literature upon seasonal variations in breeding is not so scanty. The results obtained at Kikori agree with those of Newstead & Davey in Nyasaland (1914); they concluded that "breeding continues throughout the dry season, but that there is some evidence that breeding may be more extensive at the commencement of the rains and possibly also at the end of the wet season than during the dry months" (Newstead, 1924). All authors seem to agree that breeding diminishes during the middle of the heavy rains.

Effect of season upon duration of pupal period.

The influence of temperature upon the pupal period is well known (Austen & Hegh, 1922; Newstead, 1924). In the colder months of the year the pupal period increases, whereas it decreases in the warmer weather. All information obtained upon this subject is given in Table VIII.

The pupal periods given afford only rough estimates of the duration; they are obtained on the basis that the last emergence from a large batch of puparia has come from the last puparium deposited.

Since the batches are large in numbers, it is probable that the last puparium was deposited near the date of collection.

TABLE VIII.

Effect of Season upon the Pupal Period.

Month				Pupal period	Mean max. temp.	Mean min. temp.	Mean monthly temperature
August 1928	...	...	...	53 days	—	—	—
Sept. 1928	...	...	...	36 "	—	—	—
March 1929	...	...	...	29 "	—	—	—
April	"	...	...	31 "	—	—	—
May	"	...	...	42 "	—	—	—
June	"	...	...	51 "	77.2°F.	53.3°F.	*65.3°F.
July	"	...	...	51 "	75.6°F.	55.8°F.	*65.7°F.
August	"	...	...	48 "	79.3°F.	55.2°F.	*67.3°F.
Sept.	"	...	...	41 "	83.2°F.	57.4°F.	*70.3°F.
Jan. 1932	...	...	...	38 "	83.8°F.	62.4°F.	70.9°F.
Feb.	"	...	...	34 "	83.5°F.	61.2°F.	70.4°F.
March	"	...	...	32 "	81.5°F.	62.9°F.	69.8°F.
April	"	...	...	38 "	78.4°F.	63.7°F.	68.5°F.
May	"	...	...	48 "	74.0°F.	61.7°F.	66.0°F.
June	"	...	...	52 "	73.1°F.	57.7°F.	63.2°F.

*These mean monthly temperatures are approximations, being the means between maximum and minimum temperatures.

Female activity as related to season.

It has been found that freshly emerged females do not tend to be inactive to man as do old females. Presumably the stimulus of hunger in young female flies searching for their first meal does not permit of their being seclusive in habit. In order to cut out the emergence factor, which would tend to mask the effect of season upon female activity by increasing the female percentage at times of emergence, the percentage of old females among old fly has been studied.

A comparison of the old female percentage upon all fly-rounds throughout the year, during four years, convinces the writer that season plays no part in the fluctuations in female activity towards man. He is in complete agreement with Fiske who, writing upon *G. palpalis* (1920), says: "Explanations for variations in sex ratio must be found in the purely local conditions of life, and not in climatic or seasonal differences." For example, the feeding-grounds invariably have a high female percentage and the true habitats a low percentage. From day to day the degree of female activity towards man will fluctuate in each area. These daily fluctuations are believed to be mainly influenced by hunger. Excessive hunger

will make the females less particular in their preferences and they will come to man in great numbers. As Newstead wrote in 1924—"Hunger due to scarcity of hosts will cause the seclusive habits of the females to be given up entirely."

There appears to be a tendency for the female percentage to rise at times when game are concentrating; this matter will be discussed later. In conclusion the female activity varies according to locality and hunger, but not according to season.

Fly density as related to seasonal grass fires.

The following statements refer to observations made upon the effect of *ordinary* seasonal grass fires upon *G. morsitans*, such as annually sweep into the escarpment from the Masai Steppe; *not* upon controlled fires that have been artificially held up for late burning. If a fly-round is done the day before the fires, and then again on the day after the fires, the total catches for each round will be about the same. However, the distribution of the fly will be found to have changed entirely. Areas that formerly supported thick fly and have since been cleanly burnt will be found evacuated, and islands of bush that escaped the fire will yield abnormally heavy densities. On the S.E. Kikori round there is a *Berlinia* wood that projects out from the main belt and is surrounded by *Combretum* savannah or open "mbuga." The density in this wood increases considerably immediately after the fires, whereas the open country is depopulated; the *Berlinia* wooding supports such poor grass that it is never cleanly burnt.

One of the reasons why both *Berlinia* and *Brachystegia microphylla* communities are favourable to *G. morsitans* as a true habitat is that fierce fires rarely penetrate them. It is believed that ordinary fires rarely kill the adult fly, which finds sanctuary in the unburnt islands of vegetation. *G. morsitans* has been watched flying ahead of a poor fire that was creeping through *Berlinia* wooding towards the road. The fly seemed quite unperturbed, but were abnormally dense.

A certain number of puparia deposited under rotten logs must certainly be destroyed when the log itself is burnt to ashes, as frequently happens. At the same time fire is beneficial to tsetse in that it causes many old trees to fall down, and thus increases the number of attractive log sites. Chorley (1929 b) concluded that fire concentrated the tsetse along the shady water courses, and that it had no effect upon the puparia. Simpson (1918) reached the same conclusion in the Gold Coast.

A study of the fly-round graphs shows that there is no immediate drop in fly density after the fires, but that if density was falling before the burn it will continue to fall and an increased drop will occur about a month later. If density was not already decreasing at the time of the burn, it will decrease some time afterwards. It is believed that fires merely accelerate and accentuate the features of the late dry season. The gradual process of leaf-fall in the open savannah and the temporary evacuation of this country by fly are accelerated by the fires; the rising temperature and evaporation are accentuated by the burn. The adverse effects of low humidity and heat are greatly heightened by the burning of grass and the complete defoliation of the trees. The radiation from the black ash-strewn ground becomes intense, and the fly density decreases rapidly owing to the supposedly reduced longevity of fly under such extreme climatic conditions (see p. 127). The importance of the fires was discussed on p. 120, where the effect of a very poor burn at Kandaga was compared with the effect of good fires at Kikori. It was shown that if fires are excluded, the great decrease in fly numbers in the late dry season is averted, but that afterwards the fly density steadily decreases—it is believed, because of the thick grass growth and poor visibility, which are inimical to both fly and game.

In conclusion the fires are considered to affect the fly community indirectly through accelerating and accentuating the unfavourable conditions of the late dry season.

Fly concentration as related to season.

Christy (1918) and Jack (1920) describe two types of fly migration. (1) An increase in the size of the fly belt due to an increase in the numbers of fly. Such an expansion of the fly community was described on p. 115, where it was stated that in dry years, when the fly density is very great, *G. morsitans* will spread out from the true habitat and will attempt to utilise as breeding-grounds unfavourable vegetation communities, such as *Acacia usambarensis*. In unfavourable wet years the tsetse may be driven back to the true *Berlinia-Brachystegia* habitats. (2) Fly concentration in the dry season, and dispersion in the wet season.

Shircore (1914), Jack (1920), Swynnerton (1921), Harris (1930) and others, have described the concentration of fly in places where the vegetation is non-deciduous. The fly may either concentrate in the riverine vegetation along streams, or it may concentrate in the bush surrounding "vleis," which is non-deciduous because of the sub-soil water. Newstead (1924) reviews this subject in his book.

At Kikori an apparently different state of affairs is found, though it is similar in principle. There is no non-deciduous vegetation in most parts of the fly-belt, and so *G. morsitans* concentrates in the large *Berlinia-Brachystegia* woods which afford the best shade conditions obtainable in the district. The shadows thrown by the crowns of these trees produce relatively good shade. Thus *G. morsitans* evacuates the open savannah for the large woods that form the true habitat.

Owing to the size of these *Berlinia* and *Brachystegia microphylla* communities a concentration of fly, as given by increased fly density, is not discernible, owing to the seasonal decrease in fly density that is taking place at this time throughout the community. One only knows that fly are concentrated because, whereas they previously occurred all over the fly-belt, they are now practically confined to the true habitat.

Dr. Jackson, working in the Western Kondoa fly-belt, finds the more normal type of obvious concentration. In the dry season tsetse become more numerous in *Berlinia-Brachystegia* woodland immediately surrounding "vleis." Owing to the small size of these "vleis," which are only about 75 yards across, the fly appear to an observer to be concentrated within them; in reality they are probably living in the shade of the surrounding woods and fly out to attack the investigator. Passing through *Berlinia* woods in this country one finds fly more numerous on the edge of "vleis," probably because the trees are almost non-deciduous owing to sub-soil water.

At Kikori the "vlei" is represented by an "mbuga" that may be a mile across and three miles long. These "mbugas" are much drier, having no sub-soil moisture; they are usually cleanly burnt and fly are only met with on approaching the surrounding *Berlinia* woods. The fringing trees are completely deciduous, as are all trees in the community.

It is possible that *G. morsitans* at Kikori is more abundant in that part of the habitat that fringes on the "mbuga," but owing to the huge size of the periphery such a concentration, if existent, is too small to be measured. The Kikori "mbugas" do not support young grass after the fires, owing to lack of sub-soil moisture; on the contrary they are barren, inhospitable stretches of ash-strewn ground, and so the game tend to stay in the *Brachystegia-Berlinia* woods where there is shade, and where there are patches of unburnt grass. Dr. Jackson finds that fly distributed throughout the true habitat concentrate in the dry season in a small circle surrounding a "vlei," whereas the writer finds that the fly that had been distributed in an "mbuga" or huge dry "vlei" evacuate the latter and are absorbed in the surrounding habitat.

By way of conclusion, true concentrations of the normal type are not found at Kikori. The open savannah is evacuated by *G. morsitans* after leaf-fall, its population being absorbed into the true habitat.

2. The Game Factor.

This factor is considered to be the least important of the three great factors – season, vegetation and game.

Provided that there is a sufficient food supply, this factor ceases to be of interest ; it is surprising that when game seems to be exceedingly scarce, fly continue to appear well-fed. Probably the ubiquitous wart-hog, which is a favoured host, is quite capable of supporting a fly community.

There is no correlation between abundance of game and abundance of tsetse ; on the contrary, tsetse is scarcest in the late dry season when game is exceedingly common, owing to the arrival of great herds of migratory game from the waterless Masai Steppe ; fly is most abundant when game is relatively scarce and dispersed owing to abundant water supply.

Fly appear hungrier in the late dry season than at any other time of year, this being due to the high evaporation which makes them require food more often (see Dr. Jackson's recent conclusions p. 128). At Kikori, provided that the food supply is sufficient (and very little appears to suffice), the game factor ceases to be of primary importance in the existence of *G. morsitans*. The effect of game upon the tsetse is only noticeable when large concentrations of game are taking place ; these produce fluctuations in the apparent fly density and female percentage, but are of no practical importance. The convergence upon the watering places by game entering the fly-belt attracts many following fly into the neighbourhood of the concentration ; this importation of fly from other areas naturally increases the density. A maximum fly figure is reached after the rains have broken because the game immediately disperse, leaving behind many gorged fly, which having digested, renew their activities and attack man with vigour owing to the disappearance of their hosts. These tsetse soon disperse as they rove through the bush searching for their late food supply, and fly density reaches the level which is appropriate to the season.

G. morsitans cannot follow the migratory game in their retreat to Masai-land because of the great grassy steppe which bounds the fly-belt in this direction. When game are concentrated around pools and also rest in their vicinity, the fly density at the spot appears very low, presumably because the tsetse are all absorbed with their hosts. Outside this core of the concentration fly density is high, presumably because the fly taken are those that are coming into the area in search of the game concentration. When the game disperse, the increase in density is most marked in the core as now the attentions of the fly, that were absorbed in their hosts, is freed, and they notice the presence of man.

Another feature of the game concentrations is the rise in the female percentage. This is explained by the concentration of game at one point, which leaves much of the area tapped by the fly-round devoid of favoured hosts. The females, owing to excessive hunger, lose their strong game preference and attack man more readily.

The N.E. Kikori round supports a permanent population of game ; greater kudu and wart-hog are considered the most important species. Game is always fairly common in the true habitat, where kudu, zebra, waterbuck and wart-hog are usually present.

The writer stresses the importance of wart-hog because they do not wander far from their burrows, families of them being always met with in certain places, year in and year out. The other game may wander a considerable distance, so that engorged tsetse may find a few days later that they have lost touch with their late hosts. Harris (1930) is also of the opinion that *G. pallidipes* in Zululand is frequently losing touch with its hosts, owing to the game having moved away while the fly are digesting.

Greater kudu are important because their habits are also localised. This exceedingly shy antelope always lies up during the day-time in the riverine vegetation bounding a stream, or in some small thicket, where it must be an easy prey to hunting tsetse. A kudu bull once shot was surrounded by a swarm of fly of which 61 were caught; it was noticed that the thin skin near the animal's testicles was much inflamed, probably owing to the bites of *G. morsitans*. Breeding sites cannot be correlated in this fly-belt with game stamping-grounds or resting-places. The attractiveness and suitability of the actual site seems far more important than the presence of game in the immediate vicinity.

Conclusions.

1. Provided that the food supply is sufficient, the game factor ceases to be of major importance. An apparently small game population suffices the needs of a large tsetse community.
2. When game is most abundant, it happens that tsetse is scarcest. When game is scarcest tsetse is most abundant.
3. The fauna of the *Brachystegia microphylla* hills is not subject to game movements; it is permanent.
4. The plains are subject to the arrival of migratory herds of game in the late dry season.
5. Only large game movements produce noticeable effects upon the fly community.
6. While the game are concentrated around the water the fly density appears low in the centre of the concentration but high in the neighbourhood.
7. When the game disperse fly density becomes very high in the vicinity of the core of the concentration, and remains high in the neighbourhood.
8. Before long the fly disperse and a normal true seasonal density is once more apparent.
9. The concentration of much game in an area causes an increase in the activity of females towards man within the fly-belt.

3. The Vegetation Factor.

Brief description of the vegetation of Kikori.

A description of the vegetation of this district, in so far as it affects *G. morsitans*, has already been published together with a vegetation map of Kikori showing the fly-rounds (Nash, 1930); hence only a very short mention of the most important communities need be made here. The hills forming the escarpment are clothed in *Brachystegia microphylla*, which gives good shade and retains its leaves for a long time. These woods offer the fly attractive shade, and admirable, well-drained, rock breeding-sites formed by outcropping slabs of rock. Most of the breeding for the whole fly-belt occurs in these hills. The *B. microphylla* woods afford the key to the fly position. Except for this belt of wooding *G. morsitans* would probably have been exterminated by the torrential rains of 1929-1930 (see p. 115).

At the foot of the escarpment one finds communities of *Berlinia globiflora*. This species affords good shade and log breeding sites. It is a much more important type in dry years than in wet, when the fly are forced back into the hills for their breeding. *Combretum zeyheri* savannah succeeds the *Berlinia*, or *B. microphylla* if *Berlinia* is absent. As such it forms a zone, transitional between the breeding area and the open feeding-grounds.

Acacia usambarensis wooding forms a belt beyond the *Combretum* savannah. It also forms a transitional zone, though in dry years it may form a minor breeding

ground. In the "mbugas" that occur within the fly-belt one finds *Acacia seyal* and *Acacia formicarum* and *drepanolobium* (*Gall Acacias*). A drier type of "mbuga" also occurs; it supports a thin stand of *Combretum*. These "mbugas" are important as feeding-grounds of the fly, and support a small community of hungry tsetse, composed of ever-changing individuals. None of these species form habitats suitable for permanent occupation by *G. morsitans*. Large areas of these plant communities are almost fly-free.

Vegetation distribution as compared with fly distribution.

Some of the conclusions reached upon this subject have already been published (Nash, 1930); but as they were amassed from data obtained from fly-rounds that had only been carried out for one year, they probably did not appear to be very convincing. It seems desirable, however, to repeat these conclusions since they have now been confirmed year by year for four consecutive years, thus proving the value of the writer's method of fly-rounds. In reviewing a fly position, and deciding what vegetation communities afford the key to the local problem, a four-year survey would be impracticable, so that it is important to know that valuable results can be obtained after only one year. The following results have been obtained by combining the data from all three fly-rounds. They are based upon nearly 200,000 flies caught over nearly 26 linear miles of fly-round during four years (Table IX). The data from each of the three fly-rounds taken separately agree with the results given below. Those specially interested in this subject are referred to the Appendix, where each round is dealt with separately. It will be seen from Table IX that the whole of the N.E. Kikori round is an apparent male area as compared with the other two rounds. It is characterised by high fly density and low female and young fly percentages, all factors which tend to show that it is mainly a breeding area. It will be noted that half the total females caught on this round are freshly emerged individuals.

TABLE IX.
Fly-round Data for Four Years summarised.

Round	Length	Total fly caught	Total ♀♀	♀ %	Total pregnant ♀♀	% of pregnant ♀♀	Total young fly	Young fly %	Total ♀ young fly	♀ % among young fly	♀ % among old fly
N.E. Kikori Round	6 miles 1,260 yds.	109,221	6,745	6	238	3.5	11,054	10	3,116	28	4
S.E. Kikori Round ...	7 miles 230 yds.	60,638	10,725	18	256	2.4	12,232	20	4,369	36	13
S.E. Kandaga Round (3½ years only)	11 miles 1,382 yds.	24,203	4,205	17	203	4.8	4,794	20	1,586	33	13
Totals for nearly 26 miles, representative of the whole fly-belt ...	25½ miles	194,062	21,675	11	697	3.2	28,080	14	9,071	32	5

Vegetation distribution as compared with fly density.

Comparison between the fly preferences for vegetation communities represented by several fly-round sections, passing through different woods of the community, is rendered possible by the use of the "flies per boy-100 yds." unit. The figures in Table X have been obtained by adding up all the fly caught on each section representative of each vegetation community for the four years in question. The total number of fly thus obtained is divided by the number of times the community

was visited, thus giving the average number of fly per visit, per vegetation type. This figure is then converted into number of "flies per boy 100 yds." by the formula :—

$$\frac{\text{No. of fly} \times 100}{\text{No. of boys} \times \text{distance traversed}} = \text{F.B. 100 yds.}$$

A figure is now available that will show what vegetation communities have been most favoured by fly during four years. In Table X, 10 different vegetation communities have been arranged in order of the fly density that they can support. It will be seen that the *Brachystegia microphylla* woods that clothe the escarpment prove far more attractive to fly than any other community. Clearly this is the vegetation type that affords the key to the local fly problem.

The *Acacia usambarensis*, *Berlinia* and *Combretum* communities that occur immediately beneath the escarpment (see p. 137) and fringe the *B. microphylla* zone can support a fly density that is only about one-third that of the *Brachystegia*. The remaining six vegetation types of the plain are clearly of little importance, and can only support a low fly density.

TABLE X.

Vegetational Preferences of Fly as given by three Fly-rounds in four Years.

Order of fly preference	Vegetation community	Average F.B. 100 yds.	Number of representative sections
1st ...	<i>Brachystegia microphylla</i>	5.6	2
2nd ...	<i>Acacia usambarensis</i>	2.3	3
3rd ...	<i>Berlinia globiflora</i>	1.8	4
" ...	<i>Combretum</i> — <i>Terminalia</i> savannah	1.8	8
4th ...	<i>Acacia spirocarpa</i>	0.7	1
5th ...	<i>Ac. campylocantha</i> and <i>Ac. xanthophloea</i> , surrounding a moist thicket	0.4	1
6th ...	Clearings around settlement	0.3	2
" ...	Open " mbuga " with a few gall acacias	0.3	2
7th ...	Gall acacias thickened by <i>A. senegal</i> or <i>Commiphora</i>	0.2	1
8th ...	Cultivation	0.04	4

The data obtained from this Table, and from an investigation of the fly breeding areas, indicate that should one desire to reclaim this fly-belt by means of clearing, it should be sufficient to clear only the *B. microphylla* wooding, and the *Berlinia* in which fly also breeds. The remainder of the fly-belt would almost certainly disappear in course of time.

This order of fly preference is identical with that obtained after only one year. The figure obtained for those communities tapped by only one fly-round section are clearly of less value than those tapped by several sections (see last column Table X).

It has also been found that the fly density along a road varies according to the fly preference for the vegetation through which the road passes ; and that no road or path concentrations of fly exist. The fly density along a road, passing through a certain vegetation community, is invariably lower than in the same community off the road. Numerous examples of both these two results can be found in the Appendix.

Vegetation distribution as compared with the distribution of female and young fly, as apparent to man.

The writer wishes to emphasise that, in future, when he mentions the female percentage or preference, the phrase "as it appears to man" should always be understood. It will be seen that in the experiment with bait cattle the percentage of females appearing to man gives a very false impression of the numbers of females present (see p. 144). The value of the female percentage figure lies in the fact that, when it appears abnormally low, one can be almost certain that the females are really abundant, and that there is much breeding in the area ; when the female percentage is high there will be no females remaining inactive in the vicinity, and no puparia will be found. On the other hand the freshly emerged fly percentage is considered to give a much truer indication of the proportion in the area. A glance at the last two columns of Table IX will show that the female percentage among the young fly is uniformly high on all rounds, whereas among old flies it is low,

TABLE XI.

Order of Female and Young Fly Preferences based on all Fly-rounds for four Years.

Order of preference	♀ %	Nature of vegetation	Young fly %	The number of representative sections	
1st	35	" Mbuga "	32	4	Feeding grounds
2nd	28	Clearings and cultivation ...	32	6	
3rd	20	Roads	27	11	
4th	18	<i>Acacia spirocarpa</i> wooding ...	19	1	Transition types
5th	16	<i>Acacia usambarensis</i>	15	3	
6th	13	Thick <i>Combretum—Terminalia</i> wooding	15	7	
7th	10	<i>Berlinia globiflora</i> wooding ...	14	4	Breeding areas and true habitats
8th	2	<i>Brachystegia microphylla</i> ...	6	2	

particularly so on the N.E. Kikori round which is mainly a breeding area. Clearly old females are not attracted to humans, and usually remain inactive when man passes, unless urged by excessive hunger (see p. 144). Young fly do not show this dislike to man, probably because they are always excessively hungry and are actively employed in searching for their first meal, so that there is no likelihood of their remaining inactive for long. Nearly one-third of the total fly caught in the feeding-grounds are freshly emerged individuals. This tremendous proportion is in itself evidence that young fly cannot be inactive, and that they do concentrate in the feeding-grounds. Once a fly has fed it is no longer considered a young fly, and its hardness makes it easily recognisable.

It will be seen from Table XI that young fly are most commonly met with in those types of bush where females appear to man, that is, in the feeding-grounds. The agreement in order of preference of both types of fly is very striking. It should

be noticed that young fly are scarcest in the *Brachystegia microphylla* and *Berlinia* breeding-grounds, where they emerge, and that they are not abundant in the transition areas between breeding- and feeding-grounds, but that they are abundant in the open "mbugas" and on roads. This again would strongly support the supposition that young fly on emerging migrate to the feeding-grounds (Nash, 1930; Jackson, 1930).

Notice that the large percentage of the fly taken in these places are either females or freshly emerged fly. The high percentages found in cultivation and native clearings indicate that, of the very few fly met with, many are either young fly or hungry females that have followed natives along the roads into the settlements. The female and young fly percentages along roads vary as the attractiveness of the vegetation through which they pass. The percentages are higher on the road than in the surrounding vegetation, especially the young fly percentage.

It is safe to say that there is a concentration of young fly along roads. Comparison between Tables X and XI shows that the female percentage is highest in those places where fly density is lowest. Lamborn (1916) also noticed this point.

Vegetation distribution as compared with the distribution of pregnant females, as apparent to man.

The density is expressed as "pregnant females per boy-10,000 yds.," as will be seen from Table XII, where the vegetation communities are arranged in order of preference.

TABLE XII.

The Pregnant Female Preferences based on all Fly-rounds for four Years.

Order of pregnant ♀'s preference	Vegetational type					Mean pregnant ♀♀ per boy 10,000 yards	Number of representative sections
1st	...	<i>Combretum</i> wooding	...	...	...	0.93	7
2nd	...	<i>Acacia usambarensis</i>	...	...	...	0.92	3
3rd	...	<i>Berlinia globiflora</i>	...	...	...	0.85	4
4th	...	<i>Brachystegia microphylla</i>	...	...	...	0.50	2
5th	...	"Mbuga"	...	...	...	0.43	4
6th	...	Roads	...	...	...	0.25	11
7th	...	Cultivation and clearings	...	...	...	0.03	6

Total ♀ fly caught=21,675, of which 697 were pregnant females=3.2%

It is obvious that pregnant females are very rarely taken. Though some are met with in the *Berlinia* and *Brachystegia* breeding-grounds, yet most are found in the *Combretum* and *Acacia usambarensis* wooding, which was described in Table XI as forming the transition between breeding-area and feeding-ground proper. In the latter pregnant females are scarcest.

These facts suggest that the pregnant female that comes to man is unwilling to go far afield for food, and that she prefers to hunt in the *Combretum* and *Acacia usambarensis* wooding that borders the breeding-area, whither she may be forced to return at short notice for the extrusion of her larva. Possibly she prefers to hunt in the transition area rather than in the breeding-area itself, because she is desirous

of avoiding the attentions of the pestering swarms of males that abound in the *B. microphylla* wooding (Lamborn, 1915 ; Nash, 1930). Another possible explanation is that pregnant females prefer game blood, and tend to ignore humans in the breeding-areas as do females generally (*vide* p. 144). If, however, failure to find food has driven them into the transition areas, then hunger may make them accept human blood.

4. Activities of the Fly Community.

Before a satisfactory concept of a community of *G. morsitans* could be realised, it was essential to fill in certain gaps in the knowledge of the ecology of the insect, treating it as a community and also as an individual. This chapter contains a rather miscellaneous collection of results from special experiments devised to throw light upon certain points, vital to a proper understanding of the life of *G. morsitans*.

Fly activity at night in both habitat and feeding-ground.

This subject was investigated by the writer and Mr. Moggridge, of this Department, in order to see whether fly hunted at night. It was felt that possibly the hiding female element in the true habitat might hunt by night, in order to avoid the attentions of the males. Fly catches were made in the *Brachystegia microphylla* wooding during July, August, and September 1930.

It was found that fly remained active until only a quarter of an hour after sunset, and that after this time they were rarely seen. During these three months, in the first half hour after sunset a total of only 65 males and 2 females was taken, females being almost as scarce as in the daytime. From 30 to 60 minutes after sunset only one male and one female tsetse were caught during the whole period, so that it would appear that in the true habitats females do not become active after dark, and that tsetse of both sexes become inactive shortly after sunset.

This experiment was repeated in a feeding-ground where the female percentage is always high, and the fly density low. The area chosen was in open *Combretum-Terminalia* "mbuga."

Catches were also made here for the first hour after sunset, and again fly activity almost ceased after the first quarter of an hour. In the first half-hour after sunset a total of 12 males and 7 females was caught during the period. Between 30 and 60 minutes after sunset only one male was caught. It was again concluded that tsetse of both sexes become inactive shortly after sunset.

From August to December 1930 other members of this Department kindly kept notes of fly which attacked them after 6.30 p.m. During this period 16 captures were made, the sexes being represented in equal numbers ; all these tsetse were hungry, and most were young flies.

Despite these results the writer would hesitate to be dogmatic and say that there is practically no feeding by fly at night, because many reliable observers have stated that they have been attacked while sitting up for game over water-holes on moonlight nights, or while walking along roads. Mr. St. Clair Thompson kindly made notes for the writer when he was sitting up over a water-hole at which elephants were accustomed to drink. He says that the night was cool and cloudless and that the moon was in the second quarter. Between 9 p.m. and midnight he caught six *G. morsitans* ; the sexes were equal, and half the catch was composed of young flies. The components of this catch are typical of a place where fly is hungry.

It seems probable that fly are not really active at night and that they cannot see efficiently even by full moon ; however, if fly are extremely hungry, as is usually the case when they are caught by drinking-holes or along roads, the object may pass sufficiently near to a resting fly to disturb it, or to stimulate its short-range olfactory organs, and hence precipitate attack (Nash, 1930, p. 254).

Three or four really hungry fly can be excessively troublesome and persistent and can easily produce the illusion of attack by large numbers. In literature describing the early days in the Transvaal one finds repeated references to the settlers trekking at night to avoid the tsetse (Fuller, 1923). Dr. Kirk (1865) states definitely that fly will not attack at night. Yorke (1913) and Simpson (1918) are more guarded in their statements and say that *G. morsitans* seldom attacks at night. Harris (1930) discussing *G. pallidipes* in Zululand describes the roosting of fly at dusk, and says that they cannot attack if there is no moon, unless a light is produced.

Conclusions.

1. Fly activity-practically ceases a quarter of an hour after sunset, in both true habitats and feeding-grounds.
2. Isolated instances of attack occur, and are explained by the bait passing sufficiently near to stimulate the short-range olfactory organs of a resting, but hungry, fly; if the moon is bright, a disturbed and hungry fly may see sufficiently well to alight upon the object that has awakened it.

Fly activity in early morning.

It has always been noticed that few fly are to be seen very early in the morning. In the cold spell the inactivity of the fly community may last until 10 a.m.

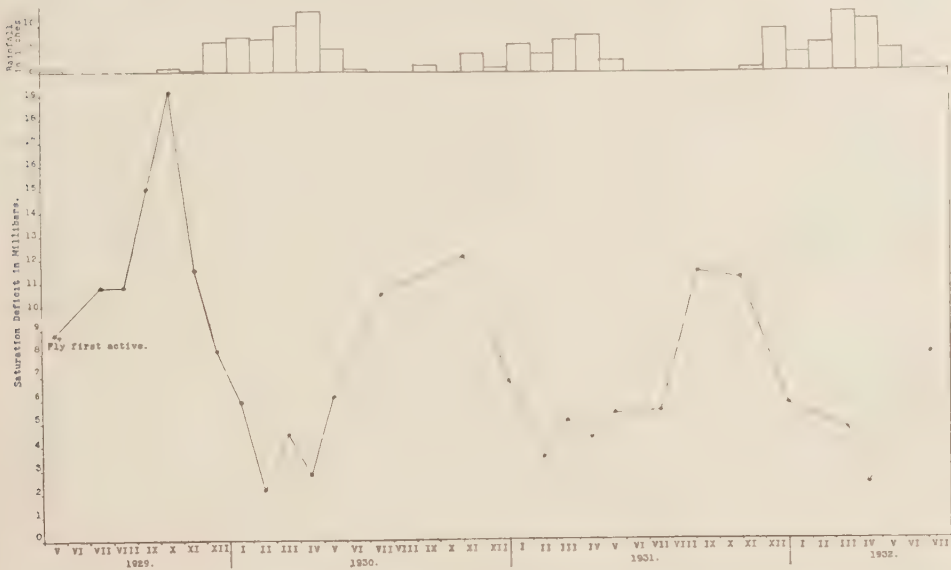


Fig. 8. The commencement of fly activity in the early morning as correlated with the saturation deficit.

Sections 9 and 10 on the N.E. Kikori round pass through the same homogeneous *Brachystegia microphylla* community, and each section supports a large fly population. On days when this round is done backwards it is sometimes observed that Section 10 yields very few fly in the early morning, but that as one approaches Section 9 the clouds start to break and fly suddenly become active. On such days the total fly caught in 10 is far fewer than in 9, whereas when these sections are visited later in the day they yield approximately similar numbers of tsetse.

The critical point at which the fly community becomes active appears to be correlated with the saturation deficit. It has been found that in the late dry season fly do not become active until a saturation deficit of at least 11 millibars has been

reached. During these months, tsetse will not appear in numbers at a lower saturation deficit. As one would expect, the critical point is not constant throughout the year. During the heavy rains the conditions are rarely hot and dry enough throughout the whole day to give a reading of 11 millibars; at this time of year fly remain inactive until a saturation deficit of about 3 millibars is attained. It has been found extremely difficult to record many readings in which fly were inactive in one section and active in the other. The available data are shown in fig. 8.

These results indicate that the awakening of the fly community into a state of activity is controlled by a combination of the temperature and humidity factors.

Conclusion.

The weather must attain a certain degree of warmth and atmospheric dryness before *G. morsitans* will commence the day's activities; the degree depends upon the season.

Female activity in the true habitat.

One of the most interesting features of the *Brachystegia microphylla* hills is that they are apparent male areas. During four years 55,000 tsetse have been caught in this country and only 2% were females. Yet these areas, which are the true habitats, serve as the major breeding-grounds of the whole fly-belt, and judging from the numbers of puparia deposited, there must be large numbers of females secluded within these woods. Large collections of puparia show that 53% of emergences are females.

It has been shown that the females in this area do not feed at night; then again, though the female percentage in the feeding-grounds is high, the actual numbers caught are very small. Should the females in the habitat always migrate to the feeding-grounds one would expect to find about 98% females there instead of a mere 30%, and also one would expect to find great numbers of them, instead of the relatively low fly densities which are characteristic. Clearly the females must feed within the true habitats.

Swynnerton (1921) made the interesting discovery that females will appear to bait cattle when they will not do so to man. It was decided to prove that females will feed in the apparent male areas by utilising cattle.

Two fly-rounds have been carried on simultaneously in these hills; they run parallel to each other and are about 300 yards apart; the visibility of this wooding is about 100 yards. On one round the bait consists of man only, and on the other, of two oxen and a minimum number of human attendants. On the bait cattle round, fly are only caught off the oxen. It has been found that at least five natives are needed to control the cattle and to catch the tsetse that come to them.

The sex proportions of the catch made by men is compared with that of men and oxen. Such rounds have been carried out for 14 consecutive months, and the following results are adduced from a total catch of nearly 9,000 fly:—

1. Only 3.7% of all the fly coming to man during this period were females. Clearly the experiment had been carried out in a typical apparent male area, as had been intended.
2. Of the fly coming to men and oxen 16.6% were females. Clearly this is not a true male area as one might suspect when catching tsetse off natives.
3. Females do feed in the true habitat, but rarely appear to man.

These results can only suggest one thing, namely that females dislike human blood, but that should they fail to find game within the true habitat they will migrate to the feeding-grounds where the stimulus of excessive hunger will make them attack distasteful man.

Fluctuations in the female percentage in both feeding-grounds and true habitat are thus explained by whether game is abundant or scarce in the habitat ; if game is scarce, more hungry hunting females will be willing to attack man. For a long time the writer believed that females were inactive in the true habitat solely because they dreaded the constant attentions of the males (Lamborn's theory, 1915), and that they sought food in the feeding-grounds because of the relatively low male percentage characteristic of such places.

Now it is shown that females are active to cattle, and presumably game, at the same time that they are inactive to man ; consequently it seems probable that man is distasteful to the females. Even so, it must be realised that the female percentage, though raised, was not raised to anything like 50% ; this may be in part due to the distastefulness of the attendant natives, but also to the females remaining inactive unless really hungry. The cause of this relative inactivity towards hosts, if it exists, may be due to a desire to avoid the attentions of the males, or it may happen that though cattle are preferred to man they are also less attractive than some wild host.

Whether females are active in the true habitat in the same proportions as males probably cannot be proved even though one were to use tame wart-hogs or kudu as bait, because one would always require the attendant human catchers. Even with traps yielding a very high female percentage the point would be hard to elucidate, as the higher percentage might be due to the unattractiveness of traps to the male element.

It has been found from figures collected over a long time that many more females appear to men and oxen than to man alone ; but this is not always the case. On some days females do not appear to either bait ; on other days large numbers of females attack both baits, and occasionally more females come to man alone, than to men and oxen. These cases are, however, the exception.

Rounds have been done continuously from dawn to dusk, and the female percentage compared hour by hour. In one hour a large number of females attack the oxen, in the next hour hardly any attack. Readings of temperature, humidity, clouds and wind have been taken at half-hour intervals throughout every round, but no correlation between female activity and a meteorological factor can be found. Catches have been made with the saturation deficit varying from 0.38 to 32.00 millibars, and with a range of temperature from 58 F. to 85 F. The females seem to appear for no rhyme or reason, and to disappear as suddenly as they appeared. Often the female percentage drops steadily hour by hour as the saturation deficit rises, until females are almost inactive. Then suddenly females appear in large numbers though the meteorological conditions have not altered. It is possible that when a wave of females occurs, they are all individuals that fed upon a herd of game some days before and therefore have all become hungry, and consequently active, at approximately the same time.

For some months it was found that females only attacked cattle early in the morning, and that their activity ceased when the saturation deficit reached a certain point. Since then, however, many females have attacked cattle at all times of day, and under all kinds of meteorological conditions. Females do appear to be commoner just before and during rain.

Conclusions.

1. Females will feed willingly in the apparent male areas or true habitats provided that the bait is not man. They will only attack man in numbers when hunger has driven them to the feeding-grounds.
2. The fluctuations in activity of females attacking oxen in male areas cannot be correlated with temperature, relative humidity, saturation deficit, clouds or wind velocity.

Fly activity in the feeding-grounds.

Feeding-grounds may be either roads or open "mbugas" or "vleis"; such localities are characterised by the high female and young fly percentages which they yield, and in addition the fly met with in the feeding-grounds are always hungry.

An "mbuga" supporting a thin stand of *Combretum-Terminalia* wooding, and tapped by Section 6 of the S.E. Kikori fly-round has been under constant study. This feeding-ground, approximately three miles long and one mile across, is surrounded on three sides by a *Berlinia globiflora* habitat; in the "mbuga," during four years 27% of the total catch has yielded females and 27% young fly; in the surrounding true habitat only 10% of the total catch has been females, and only 13% young fly.

In the northern end of this feeding-ground there are two very small wet season pools about 100 yards apart. At the end of the rains these pools retain their water for some few months, and in dry years game congregate around them after the rest of the pools in the bush have dried up; a fly concentration forms round the water-holes when the game is present. These fly concentrations were investigated and the results have already been published (Nash, 1930); briefly the following conclusions were reached:—

1. No aggregation of fly exists around the pools until the game have congregated.
2. The concentration of fly existing while the game are still drinking from the holes is composed of *ever-changing* individuals.
3. For some weeks after the pools have become dry and the game have left, they are still attractive to fly; tsetse marked and liberated over a mile away are also attracted to the dry water-holes.

From these results it was concluded that apart from the tsetse's well-known liking for a living object, even a dry water-hole, deserted by game, could also have an attractive influence. At the time it was postulated that fly were accustomed to hunt along game paths, and that as game paths from all directions converged upon the pools a concentration of fly was formed at the junction of the paths around the water; further, it was suggested that when the game concentrations dispersed, because of the desiccation of the pools, the paths owing to disuse gradually lost their conspicuousness and animal smell, and hence caused the fly to have greater difficulty in following them, until eventually the fly concentration disappeared. An experiment was then carried out in which blinded fly and fly whose antennae had been rendered functionless were liberated in this feeding-ground (Nash, 1930).

It was concluded from this experiment that *G. morsitans* hunts entirely by sight, and that the olfactory organs situated in the antennae are used for short-range work only, being of importance to the tsetse in that they receive the stimulus that produces the reflex of probing.

At the same time that these results were published Mr. Harris produced his paper upon the bionomics of *G. pallidipes* (Harris, 1930). He found that tsetse are attracted to any animate or inanimate body that has a horizontal shape and casts a good shadow, and concluded from many experiments that fly hunt solely by sight. He pictures the fly as hunting by inspecting every likely object until it finds one that is animate. In our correspondence he mentions that fly behaviour at the water-holes he has studied has been similar to that described by the writer. He explains the concentration of fly around water-holes by postulating that they are *permanently* attractive to fly, owing to the attractiveness of an outstanding tree or bush which is so often associated with the banks of such pools. The explanation will not suffice for *G. morsitans*, as no fly concentration exists until the game start to visit the pool, despite the presence of a conspicuous tree. Owing to lack of abundant shade the game do not loiter in the vicinity of the water; they drink only in the morning and

evening; yet at mid-day a stream of tsetse continues to converge upon the water-holes even though there is no game there. The attractive object cannot be the animals themselves, as there are none at this time of day, nor can it be an outstanding bush or tree because such an object is always present at all seasons, but a fly concentration is not.

It is believed that the paths made by the game are sufficient to account for the concentration. The attractiveness of paths to hunting fly can be explained by the observations of Fiske (1920) and Harris (1930), that tsetse like to follow the line separating sunlight from shadow. Except when the sun is overhead the grass on one side or the other of the path will always throw a shadow, so that, as long as the path is well-defined, a tsetse flying across the "mbuga" will see the track as a long black streak contrasting effectively with the sea of yellow grass. Theoretically half the fly that strike the path will follow it down until it ends at the pools, the rest following the path in the opposite direction. When a path falls into disuse the grass on each side will droop over it preventing the formation of any shadow, and the path will gradually become less attractive to fly.

In early 1932 it was decided to prove whether this speculation was correct, by attempting to create artificially a fly concentration around one water-hole. During February it was proved that no concentration of fly was existing around the pools. On seven occasions during this month the pools were visited, the following procedure being adopted:—

The feeding-ground was approached through the true habitat. On reaching the edge of the "mbuga" all the following fly from the *Berlinia* wooding were caught, killed, and thrown away. Having walked about 150 yards out into the "mbuga," the first stop was made, the fly being counted and placed alive in net-bags for liberation when the experiment was finished. One would expect most fly to be caught at the first stop because it is nearest the favourable habitat, which means that certain of the following true habitat fly, that avoided capture, will pursue the party out into the feeding-ground; for the same reason one would expect fewer fly further out in the "mbuga."

The second stop was about 200 yards beyond the first; some 200 yards beyond the second stop one reaches the first pool. At each of these three stopping places fly were caught, counted and temporarily retained. A hundred yards beyond the third stop one reaches the second pool; here fly were counted, marked with the colour chosen for the day, and liberated. The catching party then returned home liberating the fly, caught in the first three stops, in the true habitat.

In Table XIII the number of fly caught in February at stops one and two, and at the first and second pools is given; comparison of the total shows that most fly were caught at the first stop, which was nearest the dense fly of the true habitat. It will be seen that out of the total number of fly caught at all four stopping places combined, only 23%, or less than a quarter, were taken at the second pool. When one compares the fly density at the second pool with that of three other stopping places chosen at random, it is clear that no fly concentration existed at the second pool during February. This was only to be expected, as during the month only the spoor of one wart-hog and one hartebeest was found in the vicinity.

The heavy rains broke in late February, and as March and April are always very wet months, there was no chance of game concentrating around the pools for a very long time. Accordingly, in early March six imitation game paths were made so that they converged from all directions upon the second pool, around which a small clearing was made. Each path was about 18 inches wide, the grass being first cut and then the roots hoed up. Over four miles of such paths were constructed at the cost of 50 boy-days. On the night that the paths were completed 1.5 inches of rain fell, hence any scent left by the labourers must have been entirely destroyed.

On the day after the paths had been constructed a slight rise in fly density took place at the second pool. By the third day four times as many fly were taken as at any of the other three stops. The concentration had commenced. During March the pools were visited on ten occasions, and it will be noticed that out of the total fly taken at all four stops, 56% were taken at the second pool, as against 23% for February (Table XIII); and for four months after the construction of the paths between 50% and 60% of the total catch for all stops was taken at the second pool. The concentration continued throughout the experiment, which was brought to a close at the end of June, because during July game started to drink at the pools. Note that the female percentage for the duration of the experiment was lowest at the first stop because of its close proximity to the true habitat. The remaining three stopping places yielded high female percentages characteristic of a feeding ground.

TABLE XIII.
The Artificial Production of a Fly Concentration.

Month	1st stop	2nd stop	1st pool	2nd pool	Total fly caught on all four stops	Percentage of catch taken at 2nd pool	No. of visits per month	Remarks
	Total fly	Total fly	Total fly	Total fly				
Feb. ...	91	77	59	67	294	23%	7	Prior to expt.
i.iii.32								6 paths cut to converge on 2nd pool
March	81	53	58	240	432	56%	10	Game scarce
April	56	26	34	187	303	62%	10	..
May	62	34	32	130	258	50%	10	..
June	53	25	26	121	225	54%	10	..
♀ % for 5 months	27%	38%	48%	37%	—	—	—	—

Throughout the course of the experiment 678 fly were marked at the pools and only 17 were recaptured there, so that clearly the concentration was composed of *ever-changing* individuals. Quite a number of fly marked in the true habitat over a mile away were retaken at the pools, these being individuals that having failed to find food in the *Berlinia* wooding had come out into the feeding-ground in search of a meal.

Unfortunately the fly density in the whole district dropped towards the end of the rains so that the numbers do not appear to be very large. For April the average number of fly caught in the few minutes stop at the second pool was 19 and for May only 13. These numbers appear small, but relatively they are very large.

Section 6 of the S.E. Kikori fly-round crosses this same "mbuga" about half a mile south of the pool; the section is 1,100 yards long and the average number of fly caught per visit on the whole section was 21 for April and 5 for May. When

one realises that about 50 stops are made by the catchers in crossing this "mbuga," and that only one such stop is made at the pool, it is clear that the density at the junction of the paths is relatively high.

It had been intended to enlarge upon this experiment, having two boys catching on a path, and two at a stop some way from a path; those on the path should catch most since they would intercept fly following down the track. This experiment and others had to be given up as fly density was too small. Owing to the possible objection that the constant presence of the catchers constituted conditions similar to those of a game concentration, the pools were purposely not visited more than ten times a month, nor were long duration catches made, to see how many fly normally visited the pools in a day. Careful searching for game spoor showed that the pools were only occasionally visited by a reedbuck, wart-hog and once or twice by a few impalla; the animals did not drink but passed near the pools.

It is particularly interesting to note that fly density at the first pool remained very low throughout the experiment; when game concentrate they make paths to this pool as well, and a fly concentration also occurs. Artificial paths were only cut to the second pool, and only this pool produced a fly concentration. At the end of each month the paths were cleaned, as disuse enabled the grass to grow up rapidly.

The results of this experiment indicate that well-worn game paths may act as guiding lines for fly airways, used in this case by very hungry individuals that have entered the feeding-ground in search of food. A fly that has followed a path down to the pools probably waits some time, and then as no game arrives resumes its hunting elsewhere.

The extent of the fly concentration when brought about by the aggregation of game is greater than when artificially produced by the construction of paths. This may be entirely due to the low fly density prevailing at the time of the experiment, or it may be due to the very strong animal smell that exists around the water when game are present in large numbers, but which is absent in an artificially formed concentration. It is possible that if fly reach the junction of the paths their antennae may suffice to enable them to smell the odour of game that is easily perceptible to human nostrils; in this case the fly may be willing to remain in the vicinity for some hours, thus producing an aggregation of fly, whereas if a tsetse arrives and finds no smell it may not be tempted to stay for more than a few minutes.

The results of this experiment may be of great practical value, should any one produce an effective trap for *G. morsitans*.

By placing such a trap at the junction of paths cut to meet in a point, one trap should be able to tap a large area of country. One might need a trap at the opposite end of each path to catch those tsetse that follow the wrong way down the track.

One of the obvious drawbacks to any form of trap is the large number that would have to be employed; the importance of these results is that by constructing four paths to meet at a point, five traps would be sufficient to clear a very large area of country. A hungry hunting fly must travel a long distance in a short time, and hence is bound to meet one of the four paths, which it will probably follow until it meets the trap. It would be of great interest to repeat this experiment in a *Glossina pallidipes* fly-belt, as this species readily enters the Harris trap.

The success with which this experiment has met suggests that the vision of *G. morsitans* is of a somewhat mechanical nature, since the fly can be deceived into following artificial paths that have no imprints of game spoor and no animal smell. Harris (1930) in Zululand has shown that *G. pallidipes* can be deceived by a trap that has only the crudest resemblance to an animal. Mr. Swynnerton and Dr. Jackson have made traps that will capture small numbers of *G. morsitans* and *G. swynnertoni*, and larger numbers of *G. pallidipes* and *G. palpalis*. No work has

been done upon the length of vision of *G. morsitans*, except by Jack (1920) who puts the limit at 100 yards. Fiske (1920) found that *G. palpalis* rarely came out to a canoe that was as much as 100 yards from the shore.

Much work remains to be carried out upon the construction of artificial concentrations by the making of paths convergent upon a point. The experiment must be repeated in the true habitat, though the short, poor grass, so characteristic of the *Berlinia-Brachystegia* woodland, may make it difficult to construct well-defined paths.

Conclusions.

1. *G. morsitans* when hungry roves across the feeding-ground, and on striking a path will follow it.
2. Should a number of paths meet at a point a concentration of fly composed of ever-changing individuals is brought into existence.
3. Such tsetse concentrations can be produced naturally by the game making tracks that converge upon water-holes, or artificially by constructing such paths, so that they meet at a point.
4. Five efficient *G. morsitans* traps placed at the junction of four such paths, and at their opposite ends, should be able to tap the fly population of a large area.

5. A Concept of a *Glossina morsitans* Community.

There are two distinct types of fly movement. There is the fly advance that can only occur under exceptional conditions, which can be compared with a tidal wave, and which will be described first; then there is the normal annual wet season expansion and dry season contraction comparable to the ebb and flow of the tides.

In dry years that are favourable to an increase in fly numbers, the tsetse breeds and multiplies to such an extent that the fly community endeavours to advance beyond its natural boundaries. The tsetse will try to colonise fresh country, and in so doing will attempt to breed in vegetation communities that are not really suitable. Should there be a succession of favourable years the fly may be able to extend beyond the unfavourable zone, and to establish itself in a new area that is suitable as a true habitat. In such a case a fly advance will have taken place, the community having utilised the unsuitable country as a stepping stone towards another perfect habitat. An unfavourable wet year will eventually follow, and all the fly existing in the unsuitable country lying between the old and new habitats will be exterminated. Thus two fly-belts will now exist, and may appear to be entirely separate, or only connected by very thin fly. Should, however, the period of dry years be insufficient, the advancing tsetse may not have had time to pass across the intervening zone. In this case they may be caught before they have been able to reach country suitable as a permanent habitat, and all will perish under the inimical climatic conditions that ensue.

There is yet another possibility. The advancing fly, having temporarily established itself in an unsuitable vegetation community, may find further advance impossible owing to an insuperable barrier, such as a great grassy plain. In such circumstances the fly advance is checked and the invading tsetse are eventually destroyed, and once more the original fly-belt is restricted to the neighbourhood of the permanent habitat.

The annual ebb and flow movement is of an entirely different type. In the wet season the open savannah country produces sufficient shade to enable tsetse to roam far away from their true habitats. It is essential that fly should be able to extend the zone of their activities at such a time, as the game is dispersed throughout the bush. In the dry season after fires and leaf-fall the open savannah becomes

inhospitable; the shrubs can yield no shade, and the ash-strewn ground becomes exceedingly hot. The conditions are too severe and *G. morsitans* retreats into the true habitat, where game is abundant during the heat of the day, owing to the shade.

So far the fluctuations in the distribution of *G. morsitans* have been dealt with; there are also seasonal fluctuations in fly numbers.

If a census of the population of a fly community is frequently taken, it will be found that the number of tsetse inhabiting the area is constantly varying. The density of the fly community depends upon the season; in every year season yields to season in regular succession; the seasons form a cycle—dry season gives way to wet, and wet season gives way to dry. Similarly the density of the tsetse community passes through a cycle that follows the cycle of the seasons. When a favourable season comes round the fly population increases, when it is adverse, the population decreases. Meteorological conditions also vary according to the season, so that one naturally finds that an inclusive factor, which incorporates the major climatic factors, influences the fly density; such a factor is the evaporative power of the air, which can be said to epitomise the effect of season. The cycle in fly density follows the annual cycle of evaporation by about a month. The population of a fly-belt varies according to the evaporation, which itself condenses the varied effects of shifting seasons.

The distribution of vegetation types is of vital importance to the existence of a fly-belt. Certain types of wooding offer the tsetse community conditions that are essential, if it is to withstand the devastating effects of adverse seasons. If no such types exist in a district *G. morsitans* can never establish itself permanently in the area. In all fly-belts such vegetation communities are to be found. They must harbour sufficient permanent game to suffice the needs of the fly; they must produce enough shade to enable the tsetse to survive the rigours of an adverse season in sufficient numbers to enable the species to re-establish itself on the return of favourable conditions; they must be able to withstand the fierceness of the fires, forming sanctuaries to which the fly can retreat; lastly, they must proffer ample, well-drained breeding sites which neither flood nor fire can destroy.

A vegetation community that can produce all these essential conditions forms the true habitat of the fly. Provided such a habitat exists within the fly-belt only an abnormal and devastating calamity will be able to destroy the species. The true habitat can usually be found during the late dry season, when conditions are adverse, by discovering the area in which fly are densest and breeding continuous; a very low female percentage is also a good indicator. Within the true habitat female tsetse will rarely attack man, but they will attack oxen and presumably game. This suggests that females dislike human blood, and hence remain inactive to man, unless urged to attack by excessive hunger. The true habitat forms a permanent home for both sexes of the fly, even though it may appear to human catchers that the female element is absent.

Provided that game is always sufficient in the home, other vegetation communities are not of vital importance to *G. morsitans*; however it often happens that individual tsetse fail to find food within the habitat, and excessive hunger makes them leave the ideal conditions of their home and sally out into the shadeless open "mbugas" where visibility is exceedingly good. Tsetse appear to fly through these areas at great speed, and it is probable that if there is any game they do not take long to find it; having fed, they invariably return to the nearest temporary or true habitat where they become inactive until the first stages of digestion have been completed.

These open areas are called "feeding-grounds" because the fly caught within them are always hungry, and are considered to have come solely with the intention of feeding. In such areas females show no distaste for man and attack him readily, probably because the stimulus of excessive hunger is too great to permit of their

holding to their normal food preferences. Young fly upon emergence migrate from the habitat to the feeding-grounds; probably the stimulus of excessive hunger is so great on emergence that the young fly cannot afford the delay required to search for game in the habitat, where visibility is relatively poor.

An old fly that has gorged in the home digests for some days; then when it feels slightly hungry it starts a laborious search for food within the habitat. Owing to the close stands of trees the hunting fly may pass close to game and fail to see it. At first the stimulus of hunger will be slight and the fly may loiter for mating purposes; later the stimulus becomes greater and the tsetse will hunt with increased vigour; if the fly fails to meet game, the craving for food will become so excessive that the tsetse will be forced to leave the cool shade of the habitat, and to enter the relatively unpleasant feeding-grounds.

At first it will search along the edge of the habitat, but failing to find food it will fly across the open "mbuga." Should the tsetse see a game-path it will probably follow it and may reach a drinking-hole. If the olfactory organs of the insect are stimulated by a strong smell of game it may be tempted to wait for some time in the vicinity. If no game appears the tsetse will probably fly down another path leading away from the pool and continue the search. The tsetse may easily have travelled three miles from that part of the habitat where it last digested, before it obtains a meal. Having eventually fed, the insect flies away close to the surface of the ground and makes for the nearest true or temporary habitat where it can digest in the shade.

A temporary habitat is an area where the conditions are sufficiently suitable to enable the fly to digest and even breed during a part of the year; when the season is adverse, such temporary habitats are abandoned in favour of the true permanent homes. In this fashion individual tsetse travel considerable distances, the degree of which depends upon the scarcity of food. In inhabited country roads also form feeding-grounds; the most frequented feeding-grounds are those that are nearest the home.

Pregnant females very rarely attack man; if they fail to find game in the habitat they will not venture far out into the feeding-grounds, but will fly along the fringe of the home, so that should it be necessary to deposit their larvae abundant breeding sites can be quickly reached. They have a very strong aversion to human blood.

The tsetse community rests at night, and only awakens in the mornings when the atmospheric conditions have attained a certain degree of warmth and dryness.

III. SOME FUNDAMENTAL SIMILARITIES IN THE ACTIVITIES OF OTHER SPECIES OF *GLOSSINA*.

It has been found that there is much in common in the activities of the four species of the genus *Glossina* with which the writer has come into contact; for this reason he has decided to attempt a comparison of the activities of *G. swynnertoni*, *G. palpalis*, and *G. pallidipes*, with those already described for *G. morsitans*.

1. *Glossina swynnertoni*, Aust.

The writer's experience with this species of tsetse is confined to observations made in the Masai Steppe east of Kikori, and to a fortnight spent at Shinyanga. Having come to certain conclusions the writer discussed them with Messrs. Jackson, Burt and Lloyd, of this Department, and found that their experiences tended to confirm his own opinions.

G. swynnertoni is more complex than *G. morsitans* in its environmental preferences, making it very difficult to detect the true habitats and feeding-grounds of this species. The vital fact to be borne in mind with this tsetse is that it is mainly a thicket breeder

(Swynnerton, 1923). Once this fact is grasped it is comparatively simple to account for the contradictory results obtained in studying the sex proportion when trying to detect the home and the feeding-grounds. Since *G. swynnertoni* breeds in thickets it is only fair to assume that every thicket, whether large or exceedingly small, is the core of a potential true habitat. Thickets, however small, represent for *G. swynnertoni* what *Brachystegia-Berlinia* wooding does for *G. morsitans*.

One may find a perfectly simple well-defined case of a feeding-ground adjacent to a true habitat. A vegetation community mainly composed of *Commiphora fischeri*, *Dalbergia* sp. and small thickets may run parallel to a wide road, or a road having an artificial clearing on each side of it. In this case the wooding forms a true habitat and the clearing and road a feeding-ground presenting a high female percentage and hungry fly. This is a case exactly similar to the conditions found with *G. morsitans*, the only difference being that the habitat is composed of a different vegetation type. Such a case has been observed by the writer in the Masai Steppe, and by Dr. Jackson at Shinyanga, (Jackson, 1931).

Another simple case is that of a rocky "kopje," surrounded by evergreen thickets and climbing *Ficus* sp., which rises out of an expanse of *Acacia spirocarpa* park-land. Such "kopjes" at Shinyanga produce many puparia, most of which are found under overhanging rocks. When the park country is swept by fire the fly concentrates in the thickets surrounding the base of the "kopje." Clearly the fire-resistant thickets and breeding sites form a true habitat for *G. swynnertoni*, the surrounding country being used as a feeding-ground, or temporary habitat if it contains small thickets. Large expanses of *Acacia spirocarpa* park-land are often difficult to define if one attempts to be guided by the female percentage. If, on the other hand, one considers each small thicket to be the core of a potential habitat, and the rest of the country to be a feeding-ground, the problem ceases to be difficult. If one enters an area in this park country in which thickets become very numerous, the aggregation of homes will tend to form a large habitat and one will find a lower female percentage than that found in the perfectly open country outside.

In a poisoning experiment of Mr. Bax's at Shinyanga the results suggested that the removal of all small thickets in a stretch of park country had converted the area into a well-defined feeding-ground, the female percentage having risen and the density fallen. Other complicating factors entered into this experiment, so that the results can only be said to have been suggestive.

A particularly difficult type of country to analyse is the undulating thickly-wooded bush in which the high ground supports fairly dense *Commiphora fischeri* wooding, small thickets, and long grass in the wet season; this vegetation community is frequently interrupted by small valleys which are characterised by poor grass growing on hard-pan. These valleys are mere mbuga-like depressions in which game is common; their vegetation is primarily composed of *Commiphora schimperi* and *Lannea humilis*; small thickets are usually present. Very often at the lower end of these valleys there is a stream-bed which supports riverine vegetation. During the wet season *G. swynnertoni* tends to concentrate in these little "mbugas" which could almost be termed "vleis." Fly is very scarce in the surrounding *C. fischeri* wooding, possibly owing to the long grass.

At first sight one would expect these "vleis" to be typical feeding-grounds of the *G. morsitans* type having a high female percentage and hungry fly. The surrounding *C. fischeri* should have a low female percentage and the fly should be well-fed. The *C. fischeri* wooding behaves as one would expect, but in the "vleis" the female percentage is not always high, and the tsetse are usually well-fed. The writer accounts for this by the presence of small thickets in the "vleis"; there are really many small habitats in the middle of the feeding-ground. The result is that fly, having fed in the feeding-ground, need not retreat to the bounding *C. fischeri* wooding but can digest

in the seclusion of the thickets. When digestion is only partly complete they renew their activities and appear to man as well-fed fly. Breeding can also take place in these small thickets.

The writer believes that the variations in hunger and sex proportion can be accounted for solely by the amount of thicket in the "vleis." If thicket is absent the area will form a clearly defined feeding-ground, but if abundant the fly will appear well-fed and the female percentage will neither be extremely high nor extremely low. The whole difficulty in the analysis of *G. swynnertoni* lies in observing sex proportion and hunger is due to the fact that much of the country is transitional between home and feeding-ground. Should one find clumps of *Berlinia-Brachystegia* woodland in the middle of "mbugas" in *G. morsitans* country the analysis of home and feeding-ground would be equally difficult.

In the dry season when the grass has fallen, fly are believed to become more numerous in the *C. fischeri* woodland, but the female percentage is always low. The "vleis" may, or may not, be evacuated by fly. If there is much thicket and riverine vegetation around the stream the fly concentration will continue, if on the other hand the "vleis" can provide no shade or shelter it will become like a *G. morsitans* "mbuga" feeding-ground, the tsetse evacuating the centre of the "vleis" and spreading into the surrounding *C. fischeri* wooding. Fly will continue to use the "vleis" as a feeding-ground, but the concentration will not be so well-defined as during the rains.

The writer wishes to stress the fact that he is not dogmatic in the conclusions he has reached. He has found that by considering each thicket to be a potential habitat he has been able to account for many apparent difficulties in the analysis of the sex distribution of *Glossina swynnertoni*; at the same time he has convinced himself that this species is similar to *G. morsitans* in that it has true habitats and feeding-grounds; however, much of the bush infested by this tsetse is transitional between home and feeding-ground, so that the examination of sex proportion and hunger will often fail to indicate the true state of affairs.

It must be realised that large areas of thicket, or mere clumps, are well-suited to form the cores of true habitats, since they afford shade for the digesting tsetse, breeding sites suitable to the species, and under normal conditions are fire-resistant and capable of affording a sanctuary to tsetse at the time of the burn. All that part of the fly-belt that is free from thicket can be looked upon as feeding-ground.

Concentrations of fly in the habitat, similar to those occurring with *G. morsitans* after the fires, are to be found round rocky "kopjes," and in thickets that form a barrier to the flames. The wet season concentration in the "vleis," believed to be due to long grass in the surrounding *C. fischeri* wooding, is, however, different from anything found at Kikori, and is a feature of the entirely different type of country which *G. swynnertoni* inhabits.

The writer is indebted to all the members of this Department stationed at Shinyanga for the information which they have kindly given him about the fly in that district, as it has enabled him to make this comparison between *G. morsitans* and *G. swynnertoni*.

2. *Glossina palpalis*, R.-D.

The writer's experience of this species is confined to a few days spent at Musoma, on the eastern shore of Lake Victoria Nyanza, and the following comparison between this fly and *G. morsitans* is mainly based on Fiske's work on *G. palpalis* (1920) in the north-western corner of the same lake. On reading this paper the writer was amazed at the similarity of the conclusions reached by Fiske twelve years ago to those recently arrived at by the author, who has been working on a different species of tsetse, which lives in an entirely different environment.

Fiske attacked the problem of the activities of *G. palpalis* by studying the disparity between the sexes. He concluded that "explanations for variations in sex ratio must be found in the purely local conditions of life, and not in climatic or seasonal differences." Similar conclusions were reached in studying *G. morsitans* (p. 133).

Fiske first demonstrated that a low female percentage is due to their relative inactivity, not to their absence. He then went on to prove that females are normally inactive and not to be caught except when hungry; he proved this by destroying the game on an island, thus making the fly hungry; females promptly attacked man in large numbers. From this he concluded that females are unwilling to attack man unless urged by excessive hunger. The writer came to the same conclusions when he found that females did feed in apparent male areas, but on bait cattle, not man. Fiske then discovered that fly attacked man far more readily in places where the female percentage was high; in other words fly were hungry in places where females appear to man (*cf.* the feeding-grounds of *G. morsitans*). Fiske found that though he could rapidly reduce the density of active fly on Lula Island by hand-catching, he was unable to produce any effect upon the density of fly at Crocodile Point on Bulago Island. He concluded that the fly caught at the Point were composed of individuals that did not live there, but were constantly coming in and then leaving. Since he was able to reduce the density on Lula Island he concluded that this supported a permanent population. The idea of a locality supporting a fly population composed of ever-changing individuals is exactly similar to the writer's discovery that a fly concentration at the water-holes was not composed of the same individuals from day to day.

Fiske's next experiment was of extreme interest. On Bukassa Island the shore was lined with a dense fringe of reeds only two or three yards in width and at least ten feet in height; a hippo tunnel formed a passage through the reeds, through which the prow of the canoe was forced. A catcher was placed in the bows of the canoe; the shore opposite this bow was covered in short grass and scattered clumps of thick bush forming attractive shelter to fly. Another boy was placed in the stern overlooking the water, and outer fringe of reeds. Of the fly caught from the land by the boy in the bows 14% only were females, whereas the boy in the stern who overlooked the water took 68% females. Where there was shade and shelter the females were inactive; where there was no shade females were abundant. This is exactly the same case as if a boy were stationed in the true habitat of *G. morsitans* and another just outside in the feeding-ground. The boy in the *Berlinia* wooding would invariably take a low female percentage, and the boy in the open "mbuga" a high female percentage. In other words the vegetation on shore formed an apparent male area or home, whereas the water just off the island formed a feeding-ground.

Fiske also concluded that "at the close of each period of activity flies of both sexes are moved to seek massive shelter, where they remain in seclusion during periods of inactivity." Similarly *G. morsitans*, having fed, seeks the nearest true or temporary habitat. Many more experiments were carried out by Fiske and he concludes that "flies of this species move freely about from place to place, forming continuous streams of fly traffic along the shores of lakes, banks of streams, and, it was subsequently ascertained, along the borders of woodland, game trails, or human pathways, etc." It has already been described how *G. morsitans* hunts along the edge of the habitat and follows paths, and how roads as well as "mbugas" are used as feeding-grounds.

Elsewhere Fiske states that "active females are hungry, and are actively seeking food, and that the *degree* of activity is correlated with abundance or scarcity of food. Their movements along the shore are stimulated by hunger. The movements of the males are in part stimulated by hunger, but also in part by sex instinct." This is all exactly in accordance with the findings for *G. morsitans*; it will be remembered that

it was shown that females only appear to man in the feeding-grounds, where they are exceptionally hungry, whereas males appear to man in the habitat where they are usually replete.

Repeatedly Fiske shows that where shelter is good the fly density is high, and the female percentage low; such places the writer considers to be true habitats. Fiske also shows that where shelter is poor the density is low, and the female percentage high; such places are believed to be feeding-grounds. He states that "a high percentage of females coupled with low density of males is due to insufficient or unattractive sheltering vegetation leading to a partial segregation of the food-hunting flies of both sexes from the relatively idle and satiated males." Just such a segregation appears to exist between the fly occupying the habitats and the feeding-grounds in a *G. morsitans* fly-belt. As a result of the bait cattle experiment the writer was forced to conclude that females are active to an ox in the habitat, though not to man. It is possible that a crocodile wandering through Fiske's apparent male area would succeed in attracting females, after man had failed to do so. If this were the case Fiske would also be forced to qualify his opinions, and to conclude, as did the writer, that females being only slightly hungry in the apparent male areas are not attracted by man, and that those caught away from shelter have been forced to seek food in the open, having failed to feed in the shelter of the true habitat or apparent male area. Once hunger has been sufficient to make the females enter the feeding ground, they lose their dislike of man; hence man takes many females in the open, but few in the sheltering woods. Fiske found that man was not a favoured host of *G. palpalis*.

Most of the breeding sites described by Fiske occurred under good shelter along the beach line. Puparia were also found in such places by the writer at Musoma, but far more were taken in the densest vegetation where *G. palpalis* was never seen. Lianas and creepers formed a dense canopy overhead and puparia and cases were found everywhere at about two to three inches depth in the coarse damp humus. Puparia were not confined to the normal log and rock sites, but were unearthed all over the floor of the jungle. It was found that puparia were far commoner in the middle of the true habitat than along the shore line; possibly Fiske would also have found this, if he had carefully searched such unorthodox places.

In many districts *G. palpalis* concentrates along the river-banks during the dry season (Newstead 1924). Roubaud (1920) states that *G. palpalis* is very sensitive to low air humidity and that the dry "harmattan" wind causes the fly to concentrate in the densest bush, near water. This is another indication that the densest vegetation forms the true permanent habitat of the fly. This concentration in areas where there is most shade is another characteristic of *G. morsitans*.

In conclusion it may be said that *G. palpalis* has well-defined true habitats and feeding-grounds such as are associated with *G. morsitans*; in addition both species hunt for food in the same fashion, utilising the fringe of the habitat and paths; they both concentrate during the dry season.

3. *Glossina pallidipes*, Aust.

The writer has had hardly any experience with this species of tsetse and the following ideas are based upon the information obtained from Harris's paper upon *G. pallidipes* in Zululand (1930).

This tsetse is similar to *G. swynnertoni* in that it is a thicket-breeder. Swynnerton (1923) found this fly in *G. morsitans* country in Tanganyika Territory, and remarked that it was essentially a thicket fly, and that, if scattered thickets occurred in open woodland, the fly was able to exist in the same piece of country that harboured *G. morsitans*. *G. pallidipes* differs from *G. swynnertoni* in that it requires evergreen thickets, though this is not necessarily the case in Tanganyika Territory.

Harris has investigated the breeding sites of *G. pallidipes* in great detail. He failed to find puparia under logs, in holes of trees, and at the base of trees—sites such as are used by *G. morsitans*. He then worked on the supposition that the pregnant female requires a plentiful food supply, and soil containing much humus. Since such conditions were to be found at river-sides and by wet-season pans, he investigated evergreen thickets in their neighbourhood; his search was successful. Harris stresses the correlation between breeding thickets and abundant game. If a pan dries up, the game leaves and the surrounding thickets cease to be utilised for breeding. In the dry season *G. pallidipes* evacuates the deciduous bush and concentrates in valley bottoms and places where evergreen thicket is abundant.

All these data tend to show that the evergreen thickets near water form the true permanent habitat of the fly in Zululand. Breeding is almost confined to these places; game is abundant, and the fly concentrates within them during the rigours of the dry season. Temporary habitats would appear to be the thickets round wet-season pans in the open country. As long as these pans hold water game is abundant and fly breed in the surrounding vegetation. In the dry season the pans dry up, the game leaves, and the fly ceases to breed in the neighbourhood, being forced to evacuate the area for the thickets surrounding permanent water, where the game will concentrate. Thus one has the permanent habitat representing the *Berlinia-Brachystegia* woods used by *G. morsitans*, and the temporary habitats, such as are produced at Kikori by the *Acacia usambarensis* wooding. In the late dry season *G. morsitans* evacuates the open country for the *Brachystegia-Berlinia* habitat, and *G. pallidipes* concentrates round the corresponding evergreen thickets that line streams, valley bottoms, etc.

Unfortunately the writer can find nothing in the available literature about the variations in the sex proportions as apparent to man. He would expect the female percentage to be low among the evergreen thickets lining the river-banks, and high in the surrounding open country; owing to scattered clumps of thicket forming transitional areas between home and feeding ground, analysis by sex proportions would probably be as difficult as with *G. swynnertoni*.

There is much in common between the hunting activities of *G. pallidipes* as described by Harris, and of *G. morsitans* as described by the writer. Both species have been proved to hunt by sight. Harris has repeatedly shown this, perhaps most strikingly by catching great numbers of *G. pallidipes* in a box trap, in which scent can play no part. Again, he has shown that an inanimate object with no smell may be more attractive than a living object.

Harris has come to the same conclusion as Fiske (1920) that fly hunt along the dividing line between darkness and sunlight. He finds that hunting tsetse frequent paths made by man or by animals, and describes how they tend to follow avenues and "channels" through dense bush. It has also been shown that paths are of value to *G. morsitans*, since the construction of artificial tracks can produce a fly concentration at their junction. Harris also believes that there is little, if any, tendency for tsetse to return to the place where they last fed. Harris finds that hungry fly are nomadic and that the population at a certain spot is constantly being replenished by newcomers. On five days during a period of a week 1,312 fly were attracted to an ox stationed at the same spot every day. These fly were marked and then liberated, but none ever returned a second time. Similar observations have been made for *G. morsitans*, marking experiments having shown that a concentration of fly round a water-hole is composed of ever-changing individuals.

In conclusion, it may be said that *G. pallidipes* appears to be similar to the other species dealt with, in that it has its true habitat, to which it retreats after leaf-fall and fires. This fly hunts by sight as does *G. morsitans* and its method of searching for food appears to be similar.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st October and 31st December, 1932, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance :—

Mr. M. D. AUSTIN :—1 Diapriid ; from England.

Dr. H. F. BARNES, Rothamsted Experimental Station :—60 Parasitic Hymenoptera ; from England.

Mr. S. N. BAX :—200 Formicidae and 1,000 Isoptera ; from Tanganyika Territory.

Dr. M. BENSAUDE :—4 Coleoptera and 2 larvae ; from Portugal.

Dr. H. BLUNCK :—31 Parasitic Hymenoptera ; from Germany.

Dr. F. S. BODENHEIMER :—123 Coleoptera ; from Palestine.

Mr. P. BOVEY :—11 Parasitic Hymenoptera ; from Switzerland.

Prof. W. H. BRITTAIN, Macdonald College, Quebec :—381 Coleoptera and 21 Mallophaga ; from Canada.

Mr. G. BÜNZLI :—14 Diptera, 194 Coleoptera, 8 Parasitic Hymenoptera, 30 other Hymenoptera, 102 species of Coccidae, 14 species of Aphidae, 700 other Rhynchota, 50 Psocidae, and 60 Mites ; from Surinam.

Dr. P. A. BUXTON, London School of Tropical Medicine :—133 Tabanidae, 10 *Lyperosia*, and 112 other Diptera ; from various localities.

CHIEF ENTOMOLOGIST, Pretoria :—23 Diptera, 18 Parasitic Hymenoptera, and 1 species of Coccidae ; from South Africa.

Dr. R. N. CHRYSTAL :—64 Parasitic Hymenoptera and 37 cocoons ; from England.

Mr. A. F. CLARK, Cawthron Institute :—2 species of Aphidae and 3 other Rhynchota ; from New Zealand.

Mr. G. H. CORBETT, Government Entomologist :—44 Diptera and 2 pupa-cases, 32 Coleoptera, 47 Parasitic Hymenoptera, 12 other Hymenoptera, 56 Lepidoptera, 300 Isoptera, 10 Thysanoptera, 132 species of Coccidae, 1 species of Aphidae, 10 species of Aleurodidae, 16 other Rhynchota, 3 Psocidae, 2 Thysanura, 20 Mites, and 4 tubes of bacteria ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—513 Coleoptera ; from Kenya Colony.

Mr. A. CUTHBERTSON, Assistant Entomologist :—2 Tabanidae, 5 Asilidae and prey, 2 other Diptera, 4 Lepidoptera, 2 Rhynchota, and 400 mites ; from Southern Rhodesia.

Mr. R. C. M. DARLING :—1 Bombyliid and 3 early stages ; from the Sudan.

DIRECTOR OF VETERINARY SERVICES, PRETORIA :—6 *Lyperosia* and 136 Coleoptera ; from South Africa.

Dr. J. FEYTAUD :—3 Parasitic Hymenoptera ; from France.

Mr. J. C. M. GARDNER, Systematic Entomologist :—69 Coleoptera, 64 Parasitic Hymenoptera, 79 Lepidoptera, and 4 Rhynchota ; from the United Provinces, India.

Mr. S. GARTHSIDE :—31 Parasitic Hymenoptera and 15 cocoons ; from England.

Mr. J. GHESQUIÈRE :—252 Curculionidae ; from the Belgian Congo.

Mr. F. D. GOLDING, Government Entomologists :—70 Ticks ; from Nigeria.

Mr. P. v. d. GOOT :—57 Coleoptera and 13 Lepidoptera ; from the Dutch East Indies.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—39 Diptera and 6 pupa-cases, 150 Coleoptera, 1,552 Parasitic Hymenoptera and 14 cocoons, 8 Lepidoptera, and 3 Rhynchota ; from South India.

Dr. M. GRABHAM :—3 Orthoptera ; from Madeira.

Mr. W. GREENWOOD :—44 Lepidoptera ; from the Fiji Islands.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—50 Siphonaptera, 10 Culicidae and 6 slides of early stages, 22 Tabanidae, 132 other Diptera, 125 Coleoptera, 36 Parasitic Hymenoptera, 190 other Hymenoptera, 470 Lepidoptera, 8 species of Aphidae, 93 other Rhynchota, 166 Orthoptera, 20 Planipennia, 37 Anoplura, 54 Mallophaga, and 2 Rodents ; from Uganda.

Dr. E. HANDSCHIN :—250 Parasitic Hymenoptera ; from various localities.

Mr. E. HARGREAVES, Government Entomologist :—2 *Stomoxys*, 63 other Diptera, 155 Coleoptera and 7 larvae, 128 Parasitic Hymenoptera and 2 cocoons, 610 other Hymenoptera, 341 Lepidoptera and 2 pupae, 130 Thysanoptera, 10 species of Coccidae, 3 species of Aphidae, 1 species of Aleurodidae, 79 other Rhynchota, 20 Orthoptera, 5 Odonata, 12 Trichoptera, 100 Collembola, 2 Thysanura, 20 Mites, and 25 Centipedes and early stages ; from Sierra Leone.

HAWAIIAN SUGAR PLANTERS' ASSOCIATION :—32 Curculionidae and 20 preparations of genitalia ; from various localities.

Mr. W. D. HINCKS :—13 Curculionidae ; from various localities.

Mr. W. E. H. HODSON :—5 Diptera ; from England.

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Prof. A. C. HULL :—1 Dipterous larva ; from England.

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INDEPENDENT BIOLOGICAL LABORATORIES, TEL-AVIV :—5 Diptera, 15 Hymenoptera, and 5 species of Coccidae ; from Palestine.

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Mr. F. J. KILLINGTON :—6 Parasitic Hymenoptera ; from England.

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Dr. W. A. LAMBORN, Medical Entomologist :—8 Siphonaptera, 10 Coleoptera, 300 Parasitic Hymenoptera, 2 species of Aphidae, and 50 Mites ; from Nyasaland.

Mr. O. B. LEAN :—4 Diptera, 22 Coleoptera, 12 Lepidoptera, 1 species of Coccidae, 9 other Rhynchota, and 1,046 Orthoptera ; from the French Sudan.

Dr. S. LEEFMANS :—16 Rhynchota ; from the Dutch East Indies.

Dr. R. H. LE PELLEY, Assistant Entomologist :—4 Siphonaptera, 3 *Tabanus*, 3 Hippoboscidae, 597 other Diptera and 24 early stages, 460 Coleoptera, 1,670 Parasitic Hymenoptera and 60 cocoons, 490 other Hymenoptera and 3 cocoons, 46 Lepidoptera and 15 early stages, 60 Isoptera, 30 Thysanoptera, 14 species of Coccidae, 3 species of Aphidae, 421 other Rhynchota, 5 Psocidae, 10 Collembola, 4 Spiders, and 30 Mites ; from Kenya Colony.

Mr. R. A. LEVER, Government Entomologist :—80 Diptera, 435 Coleoptera and 60 larvae, 75 Parasitic Hymenoptera and 20 cocoons, 127 other Hymenoptera, 37 Lepidoptera and 9 larvae, 5 species of Coccidae, 79 other Rhynchota, 32 Orthoptera, 2 Planipennia, 12 Odonata, 30 Anoplura, 10 Spiders, 50 Shells, 2 Worms, 29 Lizards, 3 Crustacea, 2 Birds, and 2 eggs ; from the Solomon Islands.

Dr. F. A. LEWIS, Veterinary Entomologist :—4 Diptera, 120 Coleoptera, and 6 Ticks ; from Kenya Colony.

Dr. A. DA COSTA LIMA :—43 Coleoptera ; from Brazil.

Mr. J. B. LOUGHNANE :—1 species of Aphidae and 11 Capsidae ; from Ireland.

Miss E. I. MCGILL :—6 Parasitic Hymenoptera ; from England.

Mr. R. MAYNÉ :—22 Parasitic Hymenoptera ; from Belgium.

Mr. B. DE MEILLON :—5 Curculionidae ; from the Transvaal.

Mr. A. P. MICHELMORE :—2,000 Parasitic Hymenoptera and 21 Rhynchota ; from the Sudan.

Mr. H. M. MORRIS, Government Entomologist :—229 Coleoptera, 33 Parasitic Hymenoptera, and 130 other Hymenoptera ; from Cyprus.

- Mr. K. R. S. MORRIS :—44 Parasitic Hymenoptera and 13 cocoons ; from England.
- Mr. M. C. MOSSOP, Assistant Entomologist :—76 Coleoptera, 5 Lepidoptera, 9 Rhynchota, and 3 Orthoptera ; from Southern Rhodesia.
- Mr. A. MOUTIA :—14 Hymenoptera ; from Madagascar.
- Dr. C. F. W. MUESEBECK :—1 Braconid ; from Cuba.
- Mr. J. MUGGERIDGE, Government Entomologist :—20 Thysanoptera, 235 slides of Aphidae, and 2 Anoplura ; from New Zealand.
- MUSÉE DU CONGO BELGE, Tervueren :—3 Parasitic Hymenoptera and 5 Lepidoptera ; from the Belgian Congo.
- Dr. R. I. NEL :—6 *Tabanus*, 3 *Stomoxys*, 112 other Diptera, 67 Coleoptera, 210 Parasitic Hymenoptera, 25 other Hymenoptera, 171 Lepidoptera and 10 cocoons, 20 Rhynchota, and 8 Orthoptera ; from Sumatra.
- Mr. F. B. NOTLEY :—74 Rhynchota ; from Kenya Colony.
- Mr. H. T. PAGDEN :—300 Parasitic Hymenoptera ; from Malaya.
- Mr. R. W. PAINE :—2 Oestrid larvae, 25 Coleoptera and 2 larvae, 53 Parasitic Hymenoptera, 20 other Hymenoptera, 4 Lepidoptera, 4 Isoptera, 4 Thysanoptera, 2 species of Coccidae, 2 other Rhynchota, 10 Mites, 1,000 Algae, and 2 ecto-parasites of Dog-fish ; from the Fiji Islands.
- Mr. H. M. PENDLEBURY, F.M.S. Museum :—57 Curculionidae ; from Malaya.
- Dr. B. PICKEL :—8 Curculionidae ; from Brazil.
- Dr. S. V. PILL :—2 Hymenoptera, 2 Lepidoptera, and 204 Orthoptera ; from South Persia.
- Mrs. M. C. RANT :—140 Orthoptera ; from Arabia.
- Mr. E. REITTER :—191 Curculionidae ; from China.
- Mr. A. H. RITCHIE, Government Entomologist :—4 Coleoptera ; from Tanganyika Territory.
- ROYAL BOTANIC GARDENS, KEW :—2 Bruchidae ; from Kenya Colony ; and 6 Coleoptera and a species of Coccidae ; from Fiji.
- Mr. NIHAAT SCHEVKET BEY :—13 Diptera, 9 Coleoptera, and 10 Lepidoptera ; from Turkey.
- Mr. H. W. SIMMONDS, Government Entomologist :—1 Prionid, 2 Parasitic Hymenoptera, and 210 Isoptera ; from the Fiji Islands.
- Mr. H. P. SMART, Agricultural Officer :—2 species of Coccidae and 3 Lizards ; from British Honduras.
- Mr. F. A. SQUIRE, Government Entomologist :—9 Diptera, 40 Coleoptera, 200 Parasitic Hymenoptera, 6 other Hymenoptera, 7 Lepidoptera, 17 Rhynchota, 4 Orthoptera, 5 Mites, 20 Crustacea, and 2 Bats ; from British Guiana.
- Miss M. STEELE :—2 Culicidae, and 9 early stages, 160 other Diptera and 9 larvae, 804 Coleoptera and 11 larvae, 69 Formicidae, 14 Isoptera, 228 Rhynchota, 70 Orthoptera, 4 Dermaptera, 2 Planipennia larvae, 5 Odonata nymphs, 109 Spiders, 4 Scorpions, 10 Crustacea, and 2 Rats ; from the Sudan.
- Mr. H. V. STEELE :—2 Parasitic Hymenoptera ; from Victoria, Australia.
- Dr. H. STROUHAL :—18 Parasitic Hymenoptera ; from Austria.
- Mr. C. B. SYMES, Medical Entomologist :—1 Anobiid, from Kenya Colony.
- Mr. J. S. TAYLOR :—9 Tabanidae, 46 other Diptera, 3 Coleoptera, 3 Parasitic Hymenoptera, 35 other Hymenoptera, 3 Rhynchota, 54 Orthoptera, 6 Dermaptera, and 29 Planipennia ; from South Africa.
- Mr. T. H. C. TAYLOR :—4 Diptera, 121 Coleoptera and 70 early stages, 300 Parasitic Hymenoptera and 13 cocoons, and 6 other Hymenoptera ; from Java.
- Mr. J. A. J. THOMPSON :—249 Coleoptera, 3 Parasitic Hymenoptera, 21 other Hymenoptera, 68 Lepidoptera, 133 Rhynchota, 45 Orthoptera, 9 Planipennia, and 2 Millipedes ; from Tanganyika Territory.
- Mr. M. W. F. TWEEDIE :—22 Coleoptera ; from Christmas Island.
- Dr. P. VAYSSIÈRE :—10 Orthoptera ; from French Guinea.

Mr. R. VEITCH, Chief Entomologist :—31 Diptera and 2 pupa cases, 23 Parasitic Hymenoptera and 3 cocoons, and 7 Rhynchota ; from Queensland, Australia.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—67 Culicidae, 36 other Diptera, and a large number of Eriophyidae ; from the Sudan.

Mr. H. WILKINSON, Assistant Entomologist :—223 Orthoptera ; from Kenya Colony.

Mr. G. N. WOLCOTT :—6 Curculionidae and 2 egg-clusters ; from Porto Rico.

Dr. F. ZACHER :—39 Parasitic Hymenoptera and 46 Lepidoptera ; from Germany.

THE ECOLOGY OF *GLOSSINA MORSITANS*, WESTW., AND TWO POSSIBLE METHODS FOR ITS DESTRUCTION.—PART II.

By T. A. M. NASH, B.Sc., Ph.D. (Lond.), A.R.C.S.

Entomologist, Department of Tsetse Research, Tanganyika Territory.

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INTRODUCTION.

As a result of the study of the bionomics of *Glossina morsitans* the writer came to the conclusion that there were two possible methods for destroying this fly, both of which had been suggested by other workers, but neither of which had been investigated in very great detail. Firstly, there was biological control, a method that has been strongly advocated by Simpson (1918) and many others, but which has only been tried in the field by Lamborn (1925), who unfortunately was unable to continue his experiment until he had reached definite conclusions. Secondly, there was the destruction of puparia by means of traps. This method has been broached by Lamborn (1916), who had to close his investigation prematurely because of the war; Carpenter (1923) did much work upon the subject, but as his experiments dealt with *G. palpalis* his results were not applicable to the destruction of *G. morsitans*. Accordingly both biological control and the possibilities of puparia traps have been investigated, in an endeavour to further these two lines of practical research.

IV. BIOLOGICAL CONTROL.

In approaching this subject the writer first made a thorough investigation of the parasites of the area. In 1929 he found that *Thyridanthrax* spp. were the most important parasites in the district, but all attempts to breed these insects failed. On dull days they are inactive in the insectary, and if the sun does shine they immediately batter themselves to pieces. The first part of the work done upon the subject of biological control deals with the investigation into the parasites attacking *G. morsitans* in this district; the second part deals with *Syntomosphyrum glossinae*, the species selected from the local parasites for an intensive investigation.

1. The Predators and Parasites of the District.*The Predators.*

Very few original observations have been made upon the predators in this area. Various species of ASILIDAE and *Bembex* have been captured whilst devouring *G. morsitans*. The only interesting predator observed is the larva of the beetle *Melyris pallidiventrif*, Pic (family MELYRIDAE), a species that hitherto has only been recorded from Tanganyika Territory. These larvae became a nuisance in the laboratory, as they would enter tubes containing tsetse puparia and would devour them with avidity; they are not believed to be specific to *Glossina*, but are considered to be general predators.

The larvae were abundant in October 1930, but the beetles were not seen until September and October 1931, when they became exceedingly common. Larvae bred in the laboratory upon tsetse puparia did not produce adults for ten months. The full-grown larvae bored their way into the corks of the tubes, where they pupated. The life-cycle of these beetles must be lengthy; none have ever been found devouring tsetse puparia in the bush.

The Parasites.

Throughout the course of the investigation at Kikori, puparia have been collected from all breeding areas in the fly-belt in an endeavour to estimate the value of the local parasites in reducing the fly density; in addition, the degree of parasitism among tsetse puparia collected from the true and temporary habitats has been compared.

Thyridanthrax are the most important parasites present. Mr. Potts has taken the following species at Kikori: *T. abruptus* Lw., *T. lineus*, Lw., and *T. argentifrons*, Aust. In the following account no differentiation has been made between these

three species. It will be seen from Table XIV that 6% of all emergences from tsetse puparia, collected during four and a-half years in this fly-belt, were *Thyridanthrax* spp.; clearly these parasites are of value in reducing the fly density.

TABLE XIV.

Data obtained from Collections of Puparia at Kihori during 4½ Years.

Total no. of puparia collected	Percentage dead	Tsetse ♀ %	% of <i>Thyridanthrax</i> in total emergence	% of <i>S. glossinae</i> in total emergence
5,168	19	50	6	0.2

Syntomosphyrum glossinae, Waterst., has parasitised 0.2% of the emergences. As will be seen from the first part of Table XV, this species appeared to be absent during 1928 and 1929, but small numbers have been taken during the last two years; this may be in part due to the escape of these parasites from the laboratory, where they were being bred on a large scale for an experiment in biological control; it is significant that all puparia yielding this parasite were collected on the same hill as the laboratory. Hence it may be concluded that under normal conditions *S. glossinae* is exceedingly scarce in this district and is of very little importance as a check upon the increase of *G. morsitans*.

TABLE XV.

A Comparison between Puparia collected from Three Types of Habitat.

Data	1928 and 1929			1931 and 1932		
	<i>B. microphylla</i>	<i>Berlinia globiflora</i>	<i>Ac. usambarensis</i>	<i>B. microphylla</i>	<i>Berlinia globiflora</i>	<i>Ac. usambarensis</i>
Total number of puparia collected ...	783	451	275	3,195	453	11
Percentage dead ...	13	24	28	20	19	—
Tsetse ♀ % ...	52	52	50	50	48	—
Percentage of <i>Thyridanthrax</i> in total emergence ...	9	20	22	3	2	—
Percentage of <i>S. glossinae</i> in total emergence ...	0	0	0	0.3	0	—

One emergence only of *Stomatoceras micans*, Waterst., has been recorded during the course of this investigation, and no other species of parasites of *G. morsitans* have been taken in the fly-belt.

The first part of Table XV, dealing with the years 1928–29, refers to the period before the torrential rains, when the community was flourishing and had established itself in great numbers throughout the plains (see p. 113). It will be seen that puparia taken from the *Brachystegia microphylla* hills were the healthiest—only 13% being dead, and only 9% of the emergences yielding *Thyridanthrax*. If we compare these figures with those given for the *Berlinia globiflora* and *Acacia usambarensis* woods of the plains, it is clear that the true habitat of the hills was more suited to the puparia of *G. morsitans* than was the *Berlinia* home or the *A. usambarensis* temporary habitat situated beneath the escarpment.

In the second half of Table XV the same data are given for 1931-32—the period after the torrential rains, when the fly community was recovering. It was found exceedingly difficult to obtain puparia from the plains, because they have not yet been re-colonised to any extent. Only eleven puparia could be found in the *Acacia usambarensis* wooding; hence no figures are included in this part of the Table for this vegetation type; however, 22% of these few puparia were parasitised by *Thyridanthrax*. It will be noticed that the percentage of dead puparia is now almost equal in both the *B. microphylla* wooding of the hills and the *Berlinia* wooding of the plains. The great decrease in the percentage of puparia parasitised by *Thyridanthrax* is very remarkable. It suggests that these parasites were just as badly affected by the downpour of April 1930 as were their hosts. The decrease is most marked in the *Berlinia* woods of the plains, where *Thyridanthrax* were formerly so numerous.

Attempts have been made to breed *Thyridanthrax* in an insectary, but without success; under natural conditions they are very slow breeders, taking as long as seven months to complete their life-cycle. It was decided that these parasites were unsuitable for any experiment in biological control, since they will not breed in artificial surroundings. *Syntomosphyrum glossinae*, however, was bred in the laboratory without any difficulty, and was therefore selected as the subject for an experiment in biological control, which will be described in the next section.

The data obtained from these collections of puparia have enabled the following conclusions to be made:—

1. The female percentage among tsetse emerging from puparia collected in both the hills and the plains is about 50.
2. No correlation between season and the percentage of dead puparia can be traced; on an average nearly one-fifth of the puparia collected at Kikori were dead.
3. Before the torrential rains of April 1930, puparia taken from the hills were healthier and less subject to parasitism than those taken on the plains.
4. In the years following the downpour, puparia taken from the hills were no healthier than those taken from the plains.
5. The percentage of *Thyridanthrax* emerging from tsetse puparia greatly decreased after the downpour; the decrease was most marked in the plains.
6. The percentage of parasitism by *Thyridanthrax* among tsetse puparia shows no seasonal fluctuation; certain localities may be free from these parasites at one date, and then yield many at another date.
7. Puparia deposited beneath *A. usambarensis* logs are particularly subject to parasitism by these insects; probably this is due to the hardness of the soil under such logs, resulting in the frequent occurrence of exposed puparia.
8. *Thyridanthrax* cannot be bred under laboratory conditions, whereas *S. glossinae* can be reared with ease.

2. *Syntomosphyrum glossinae*, Waterst.

Since an indigenous parasite must have already reached a state of equilibrium with its host, the liberation of a few more individuals cannot possibly produce any effect. The only chance is to upset the natural balance by a continuous mass-liberation, in the hopes that during the time of year which is most favourable to the parasite, it will succeed in the complete destruction of the tsetse puparia. For this reason it is essential that the insect chosen should be easy to breed.

A parasite that is specific to the puparia of *G. morsitans*, or whose alternate host is a rare insect, is of little value. If it is necessary to collect tsetse puparia in order

to breed the parasite, the experiment becomes impracticable. Clearly it is desirable that the parasite should have an alternate host whose puparia are readily obtained.

The writer knew of only two such parasites : *Chalcis amenocles*, Walk., a parasite of *G. submorsitans*, which will also parasitise puparia of *Sarcophaga* (Simpson 1918) ; and *Syntomosphyrum glossinae*, which was shown by Lamborn (1925) to be a parasite of *G. morsitans*, as well as being a hyperparasite of the MUTILLIDAE ; he bred it in puparia of *Musca nebulo*, Patton & Cragg, *Dacus brevistylus*, Bezzi, *Chrysomyia putoria*, Wied., and in a species of *Sarcophaga*.

Mr. Potts, of this Department, happened to obtain a number of *S. glossinae* from a puparium of *G. morsitans* and kindly gave them to the writer, who found that they bred readily upon puparia obtained from rotten meat, and has since bred them from puparia of the following species of the genus *Chrysomyia*, all of which are common : *Chrysomyia marginalis*, *chloropyga*, *putoria* and *albiceps*, Wied. ; also from *Sarcophaga haemorrhoidalis*, F. Clearly *S. glossinae* was a parasite of the type required, its alternate hosts being so easy to breed.

Qualifications of S. glossinae as a Parasite of Economic Importance.

On first considering the possibilities of this parasite the writer reviewed the literature on the subject. Lamborn (1925) attempted to breed *S. glossinae* on the large scale and to liberate the insect in *G. morsitans* country. He chose an area of 42 square miles, in the Livingstonia Peninsula of Lake Nyasa, and found that out of 935 puparia collected in 1922 only 0.4% were parasitised by *S. glossinae*, and that out of 1,083 puparia obtained in early 1923 only 0.6% were parasitised by this insect. Clearly *S. glossinae* was normally exceedingly scarce in the district. Between June and October 1923 Lamborn estimated that he released approximately 277,000 parasites. A study of the results was commenced early in 1924. In January 1924, 195 puparia collected gave 5.9% parasitism by *S. glossinae*, 160 puparia in February gave 11.5% parasitism, and 161 puparia in March gave 12% parasitism by this insect. Dr. Lamborn then proceeded on leave and the experiment was concluded.

The writer considered these results exceedingly satisfactory, as he hoped to succeed in liberating far greater numbers of the parasite.

Chorley (1929 a), working in Southern Rhodesia, concluded from his laboratory experiments that *S. glossinae* was not likely to be of any practical importance as a destructive agent of *G. morsitans*. He based his conclusions upon his discovery that *S. glossinae* was incapable of penetrating light sand to a depth of more than $\frac{1}{8}$ to $\frac{1}{4}$ of an inch, and concluded that large numbers of tsetse puparia would be inaccessible to the insect.

The writer repeated and amplified this experiment, using sand, dry and wet humus, and dry *Berlinia* leaves ; all material was taken from tsetse breeding-sites. Flesh-fly puparia were covered with various depths of the materials mentioned, and then parasites were liberated in the area above them. By recording the puparia successfully parasitised it was possible to estimate the burrowing abilities of *S. glossinae* for different types of covering. An initial experiment showed that emerging blowflies upset the surface of the soil and often exposed the neighbouring puparia ; for this reason all were first killed by treating them with water at 125.5°F. for 1½ minutes. This treatment partly destroys the attractiveness of the puparia for *S. glossinae*, and therefore the percentage of parasitism given in Table XVI should be ignored. If only one puparium is parasitised it suffices to show that *S. glossinae* can burrow to that depth.

From Table XVI the following conclusions have been reached :—

1. Dry Sand.—*S. glossinae* is incapable of reaching puparia buried by more than one-tenth of an inch of this covering.

2. Dry Humus.—*S. glossinae* can readily reach puparia that are buried by just over half an inch of dry humus.
3. Wet Humus.—During the rains *S. glossinae* will not be able to parasitise puparia buried by more than four-tenths of an inch of wet humus.
4. Dry *Berlinia* Leaves.—The parasite can easily reach puparia lying under one and a half inches of this covering.

TABLE XVI.

The Burrowing Abilities of Syntomosphyrum glossinae.

Nature of covering	Depth in inches	No. of puparia used	Parasitism %	Nature of covering	Depth in inches	No. of puparia used	Parasitism %
Dry sand from rock site	$\frac{1}{10}$	20	10	Dry <i>Berlinia</i> leaves	$\frac{1}{2}$	10	70
	$\frac{2}{10}$	20	0		1	10	50
	$\frac{3}{10}$	20	0		—	—	—
	$\frac{4}{10}$	20	0		—	—	—
	$\frac{5}{10}$	20	0		$1\frac{1}{2}$	10	80
	$\frac{6}{10}$	20	0		—	—	—
Dry humus from log site	$\frac{1}{10}$	20	25	Wet humus from log site	$\frac{1}{10}$	10	30
	$\frac{2}{10}$	20	45		$\frac{2}{10}$	10	10
	$\frac{3}{10}$	20	60		$\frac{3}{10}$	10	10
	$\frac{4}{10}$	20	50		$\frac{4}{10}$	10	10
	$\frac{5}{10}$	20	25		$\frac{5}{10}$	10	0
	$\frac{6}{10}$	20	35		$\frac{6}{10}$	10	0

Clearly Chorley's results were correct in so far as they went; the loose sand smothers the parasite when it attempts to penetrate the surface. With coarse humus *S. glossinae* can follow the interstices between rootlets, decomposing leaf debris, twigs, etc. It was apparent that this parasite would be most effective in areas where *G. morsitans* breeds entirely in humus. Dr. Lamborn, in a reply to a question from the writer, states:—"The breeding sites in my area of liberation of *S. glossinae* were all made up of light humus—very light soil full of dead leaves and twigs." Since much of the breeding in the true habitat at Kikori takes place under rock sites which have a sandy soil, the prospects of success were not too hopeful. One encouraging discovery was made; it was found that under laboratory conditions *S. glossinae* could successfully parasitise a freshly extruded tsetse larva before it had time to burrow beneath the surface of the soil. Hence if all breeding sites could be infested with the parasite, there was a chance that the larvae would be attacked before they had time to reach the safety afforded by a covering of sand.

It was decided that the experiment was well worth continuing even though it should prove a failure, since the parasite undoubtedly had possibilities in areas where the tsetse breeds in humus; hence the discovery of a sound, cheap, technique, for the breeding and subsequent liberation of the parasite was bound to prove of economic value.

The writer has proved that, in the laboratory, *S. glossinae* will attack the puparia of *G. palpalis* and produce healthy offspring. Harris (1930) proved the same for *G. pallidipes*. Both these species of tsetse breed commonly in humus, and *S. glossinae* might prove a valuable insect for reducing their numbers.

A few points in the bionomics of the parasite will now be mentioned as they are important in the assessment of its qualifications as an insect of economic importance.

1. Its power of flight is poor. This is a distinct disadvantage, but if the area is well-stocked it is probable that the parasite will slowly spread, being disseminated by the wind.

TABLE XVII.

Seasonal Variation in the Duration of the Life-Cycle of Syntomosphyrum glossinae.

Month	1930		1931		1932	
	Period in days	Mean monthly temp. (F.)	Period in days	Mean monthly temp. (F.)	Period in days	Mean monthly temp. (F.)
Jan.			20	72.7°	24	70.9°
Feb.			20	70.9°	24	70.4°
March			27	71.3°	26	69.8°
April			29	69.9°	28	68.5°
May			27	66.9°	31	66.0°
June			45	63.3°	40	63.2°
July			40	64.5°		
Aug.			39	65.2°		
Sept.			31	69.7°		
Oct.	25	70.6°	27	67.7°		
Nov.	25	72.2°	21	73.3°		
Dec.	25	72.2°	24	70.4°		

2. Its reproductive capacity. Except during the cold spell, one fertilised female, having parasitised three tsetse puparia, can produce about 130 offspring in 3 weeks; whereas one female tsetse could produce only one adult offspring 6 weeks after copulation under the same local conditions. The average number of parasites produced from tsetse puparia was 44, but the greatest number of offspring ever reared was 185 from one puparium of *Sarcophaga haemorrhoidalis*. As Lamborn (1925) points out, the larger the puparium the more numerous the offspring; this is due to the amount of food available for the parasite's larvae. Clearly the reproductive capacity of *S. glossinae* is very great.

3. The large proportion of the offspring that are females. About 87% of the total emergence are females. Chorley puts the percentage at an even higher figure.

4. Should a female fail to be found by a male, it can reproduce parthogenetically, males only resulting (Chorley 1929 a). This is important, as when the parasite is so scarce in the bush that females are rarely fertilised, they can restore the balance by producing large numbers of males, thus ensuring fertilisation in the next generation.

5. The parasite will attack a puparium after it has been deposited many days. Harris (1930) records two cases of successful attack by parasites 45 days after *G. pallidipes* puparia had formed. At the time the normal tsetse pupation period was about 50 days. The writer found that if large numbers of parasites were enclosed with *G. morsitans* puparia of varying ages, no tsetse succeeded in emerging two days after contact. If the number of parasites was not greatly in excess the period was eleven days. Possibly repeated oviposition by many females can kill the tsetse that is almost ready to emerge.

6. The duration of the parasite's life-cycle within blowfly puparia greatly increases during the cold spell; it is least at the hottest time of the year (*vide* Table XVII). The same variations are found in the pupal period of *G. morsitans* (p. 133).

Technique employed in breeding Syntomosphyrum glossinae.

The large-scale breeding of this parasite of *Glossina morsitans* is far more complicated than would appear from casual experiments in the laboratory. The parasite can be bred by almost any method, but in order to exploit the fecundity of the insect so as to obtain the maximum number of offspring from each generation, a very specialised technique must be employed.

At first three boxes were made each 2 feet square and 1½ feet in height. A sliding tray fitted into the bottom of each box, and a plate of glass acted as a lid. The parasites and blowfly puparia were inserted through tubes, fixed in the sides of the box, the former being fed by means of wicks which absorbed sugar solution from reservoirs situated outside the boxes.

This method was a failure, because, owing to the poor ventilation, the puparia became infected with mould. To rectify this the boxes were painted with Solignum which kills the fungous spores. In addition the glass lid was replaced by cloth, and ventilation holes were bored in the sides of the boxes. The ventilation was now improved, but the lighting was bad; the results were better, but still far from satisfactory. It was found that up to 79% of the fresh puparia inserted in the parasite boxes failed to become parasitised, producing only blowflies; this suggested that the puparia were too old and hard to enable the parasite to insert its slender ovipositor. The boxes were then stocked with full-grown blowfly larvae, so that *S. glossinae* might attack the puparia whilst they were still soft; the result was worse—92% of the puparia produced blowflies.

Present Method.

Twelve boxes of the same dimensions have been made out of white deal; each is ventilated by two side windows, 20 inches by 1½ inches, as well as through the roof. Both roof and side windows are covered with thin white calico; butter-muslin is useless, as the parasite can escape through the strands of the material. The lighting inside the boxes is very good, and the number of puparia lost through the emergence of blowflies has been reduced from 79% to 17%. Probably the parasite requires good lighting to enable it to become sufficiently active to oviposit.

The tray is filled with well-baked sand. A mosquito-netting bag containing infested puparia from the last batch is placed in each box. After a period, varying according to the season, of 20 to 45 days since these puparia were infested, their offspring start to emerge, and before long each box is swarming with parasites. Meanwhile it has been so timed that a supply of blowfly puparia shall be ready for the parasite's probable emergence day. For twelve days fresh puparia are added to all boxes, until each has been stocked with about 5,000 puparia.

In order to infest this number of new puparia, each box should have 900 "stud" puparia in the muslin bag, producing about 367,000 parasites. Experiment has shown that the proportion of 7 parasites to each puparium will produce a maximum yield

from each host. By increasing the number of parasites per puparium from 1.5 to 7, the average yield of *Syntomosphyrum* offspring, per puparium, has been raised from 26 to 68.

Eight days after the last fresh puparium has been added, no more blowfly can emerge, so that one can then remove the puparia, throwing away the few empty puparial shells left by the occasional blowfly that managed to escape parasitisation. The puparia are now ready for liberation.

A sample of 270 puparia is kept in the laboratory, and from this the percentage of emergence is obtained, so that one can estimate the percentage of liberated puparia that will produce parasites. Out of the sample of 270 puparia 50 are isolated, each puparium being segregated in a tube. Whenever emergence has taken place from an isolated puparium, the parasites are quieted with ether and a count is made. From these figures a second factor is obtained, namely the average number of parasites emerging from each puparium. By using these two factors an approximation can be obtained of the number of parasites emerging in the bush, provided that no puparia are devoured by predators.

The breeding boxes are kept on rough trestles in a grass hut. The trestles are surrounded by a trench filled with ashes, in order to keep away the Driver Ants; as an additional precaution the trestle-legs are smeared with bird-lime. Every crevice in the boxes must be blocked with plasticine, as the parasite is an expert at finding a way out. The parasites in the breeding boxes are fed daily on strips of blotting paper that have been moistened with sugar solution.

Breeding of blowflies and treatment of their puparia.

The blowfly puparia are mainly obtained from various species of the genus *Chrysomyia*, which lay their eggs in rotten meat. Dr. Lamborn has informed the writer that he got far better results by using puparia of *Sarcophaga* bred from human excreta; this is not possible in this district, as the natives are mostly Mohammedans and would refuse to search for the puparia.

At first, a hunk of meat used to be placed in the bottom of a petrol tin, which was suspended in the fork of a tree. It was found, however, that the meat dried up in the hot weather and that the larvae died before they were ready to pupate. Ox or antelope heads were then tried with success; the ears were cut off at the base, the blowflies laying their eggs in the auricular cavities; the larvae thrive in the moisture of the heads, and the meat does not desiccate.

Another great difficulty was the appearance in large numbers of a *Trichopria* (family DIAPRIIDAE), which parasitised the puparia in the blowfly breeding station before they were given to the *Syntomosphyrum*. This was a very serious obstacle, especially as the pest was often unwittingly introduced into the next month's batch, when "stud" puparia from the last month were placed in the boxes; consequently a considerable number of the adult *Trichopria*, as well as *S. glossinae*, would oviposit in the fresh puparia, 16% of which produced this pest, which is useless, as it will not attack tsetse puparia.

It has now been found that the best source of meat is provided by chickens, when they can be bought at the rate of five for a shilling. Seven chickens can be bought for the same price as an ox-head, and two hens will produce rather more puparia than one ox-head. The hens have their necks cut off at the base, and a ring of meat removed at the anus, but their feathers are left on, as this helps to prevent desiccation. If fowls are scarce or expensive, large hunks of meat are perfectly satisfactory until the very hot weather; then only ox or game heads, or chickens, can be used. Two hens are placed in one kerosene tin, the floor of which is lined with sand. The tins are suspended from the ridge pole of a tent by means of ropes which have been coated with bird-lime, and thus are hung in such a manner that neither cats nor insect predators can raid the meat tins, rain being also excluded.

To obviate attacks by the undesirable and useless *Trichopria*, a rather unusual technique was evolved. Yussufu Cheke, a raw but very intelligent laboratory boy, suggested that, if all the fresh puparia were boiled immediately before being given to the parasites, sterilisation would kill off any eggs of *Trichopria*. The idea sounded absurd, as one would expect that any abnormal treatment of the puparia would reduce their attractiveness for *S. glossinae*, besides destroying the nature of the food supply required by the parasites' larvae; however, it was considered that any idea was worth investigation.

At first a few puparia were placed in boiling water for one and a half minutes and were then given to the parasites. To the writer's amazement a very small percentage of the puparia were parasitised, the larvae of *S. glossinae* being able to feed upon the lifeless tissues of dead puparia and to emerge as perfectly normal adults. A few more experiments showed that at lower temperatures the percentage parasitised was much higher.

It was then decided to investigate the subject in detail. Twenty-four batches, each consisting of 100 puparia, were treated for one and a half minutes with water at twenty-four different temperatures varying from 95.5° F. to 156° F., in order to discover the effect of the treatments upon the emergence of the adult blowfly. The results, for the interesting part of the temperature range, are given in Table XVIII.

TABLE XVIII.

The Effect of Water at Different Temperatures upon the Puparia of Chrysomyia.

Mean temp. (F.)	No. of emergences	Mean temp. (F.)	No. of emergences	Mean temp. (F.)	No. of emergences
95.50°	94	120.00°	96	126.00°	0
104.00°	93	121.00°	93	127.50°	0
113.00°	94	122.00°	84	128.75°	0
115.00°	94	123.00°	73	130.00°	0
117.00°	94	124.00°	28	131.00°	0
118.50°	98	125.50°	0	132.50°	0

Out of 100 untreated control puparia 94 successfully emerged. It is clear from the Table that death occurs between 122°F. (50°C.) and 125.50°F. (52°C.) inclusive. The upper fatal limit is fairly uniform for various insects and lies on the average at about 122°F. (Uvarov 1931).

The next point was to discover at what temperature treated puparia were most attractive to *S. glossinae*. In order to determine this, many experiments were carried out in which puparia were treated for the standard period of one and half minutes with water at different temperatures. The effect of the treatment was estimated by obtaining the percentage of puparia that were successfully parasitised, and the average number of emergences per puparium. These two factors—percentage of parasitism and average number of offspring—when multiplied together give a yield factor, which is a useful unit for comparative purposes.

Table XIX gives the combined results from many smaller experiments; the temperatures in the first column refer to the mean temperature of the water during the one and a-half minutes of treatment. A comparison of the yield factors for the different treatments shows that when puparia are treated with water at temperatures

either higher or lower than 122°F. (50 C.) the yield decreases considerably. Clearly, the best results are obtained if the puparia are treated for one and a-half minutes with water that has a mean temperature of 122°F.

Referring back to Table XVIII, it will be noticed that this is the temperature at which the blowfly within their puparia are just starting to be affected by the temperature of the water. This suggests the possibility that the tissues within the puparia are most suited to the development of the parasite's offspring when the vitality of the puparium has just been affected by the temperature.

The practical value of this result is that puparia which have been placed in water at 122 F. for one and a-half minutes are still attractive to the ovipositing parasite and suitable for the development of her offspring, but all eggs of the undesirable *Trichopria* are destroyed by the treatment. Admittedly this treatment does adversely affect the yield factor, since untreated puparia produce rather more offspring (see Table XIX); however this loss in numbers is negligible compared with the worry occasioned by the admittance of *Trichopria* into the breeding boxes.

TABLE XIX.

Variations in the Yield according to the Temperature employed.

Treatment	Yield factor	Number treated
Un-treated	3,823	300
112·00°F.	2,431	300
119·50°F.	2,319	400
122·00°F.	3,463	900
123·50°F.	3,101	400
124·75°F.	2,977	400
130·00°F.	1,726	200
167·00°F.	1,120	200
193·00°F.	432	200
201·75°F.	146	200

There is yet another advantage in employing this method. When untreated puparia are inserted in the boxes it frequently happens that as many as 17% of them produce blowflies before the parasite has time to oviposit and destroy them. Unless these adult flies are removed, they cause much disturbance in the boxes, and for some reason the parasite refuses to oviposit and dies very rapidly. When the puparia are treated, rarely more than 1% produce blowflies, and those that are not successfully parasitised are found to be dead.

It may appear that this part of the investigation is rather incomplete, and that many interesting lines have not been followed to definite conclusions. The reason is that the writer's work must be of a practical nature, so that if he fortunately stumbles upon a useful discovery he is content to have made it, and cannot spend time in investigating the reason, if it is clear that it will not further the practical aspect of the subject. For instance, the exact temperature of the water needed to kill the eggs of *Trichopria* is unknown; it is sufficient for the purposes of this work to know that one and a-half minutes at 122°F. will destroy them.

All puparia brought in from the blowfly tent are always given this treatment. First they are weighed, and then it is ascertained how many degrees must be allowed if this weight of puparia is to be kept at a mean temperature of 122°F. Clearly the more puparia the higher must be the initial temperature, as the cooling effect of the sudden insertion of puparia into the water will vary according to the amount; 1,000 ccs. of water is placed in a copper bowl, and the same net-bag is always used to hold the puparia.

A table has been constructed which shows the allowance necessary when using this net-bag for varying weights of puparia. For example, if there are 200 grams of puparia, a glance at the table shows that an allowance of 9 F. is required. The water is brought up to 131 F., the puparia are plunged into the bowl, and the water is vigorously stirred; the temperature drops at once to 123°F., and by the end of the one and a-half minutes has cooled off to 121 F. The mean temperature, after the initial drop, has been 122 F. The table is not given, as it is only applicable for the particular net-bag employed.

The method is primitive but gives excellent results, and an intelligent native laboratory boy can carry out this daily routine work without supervision. Very constant results can be obtained if this treatment is always employed, and if it is arranged that the number of parasites emerging from the "stud" shall be in the proportion of about seven to each fresh puparium inserted. When this is done, about 50% of the fresh puparia are successfully parasitised, and the average number of offspring from each puparium is about 70. Since 60,000 puparia are inserted into twelve boxes for each generation, about 2,000,000 parasites are bred each month, of which 1,750,000 can be liberated. The percentage of parasitism is relatively low when compared with smaller-scale breeding experiments in which the parasite is bred in tubes upon untreated puparia.

It has been found that in practice it is better to produce a technique that is protected from sudden disasters, even though the fecundity of the insect is not exploited to its utmost. It is more satisfactory to produce a steady two million parasites a month by employing the hot water treatment, than to risk the destruction of the stock by competitive and useless parasites in an attempt to rear larger numbers.

It is vital that the supply of puparia should coincide with the emergence of the "stud" parasites. For this reason it is worth while to keep a small stock of another generation that will emerge about a fortnight before the main mass in the boxes; ten or twenty puparia kept in tubes will suffice. They are of value as indicators of any sudden fluctuation in the duration of the parasite's life-cycle. A sudden lengthening of this cycle due to cold weather may completely upset the synchronisation of the supply of blowfly puparia with the emergence of parasites. As long as this small generation is kept as an indicator, one is forewarned of such fluctuations and can make arrangements accordingly.

Normally ten days after the chicken or other animal has been killed many puparia are ready; a few will even be formed by the eighth day. In the cold season one sometimes finds a strong reluctance on the part of the full-grown blowfly larvae to pupate; the parasites may have emerged, but there are no puparia ready for them. If the bigger larvae are collected and placed in a box of sand in a room which is heated by a stove, they will rapidly pupate. If, owing to some small error in the synchronisation, many puparia are ready and the parasites are only just emerging, the puparia should not be put in the boxes, because large numbers of flies will emerge and, owing to their restlessness, will prevent oviposition by the parasite. Puparia should not be added until *S. glossinae* have emerged in fair numbers.

Using the old technique, with dark boxes and the undesirable *Trichopria* breeding unchecked, 30,000 puparia would have yielded 100,000 parasites; by using the method described, the same number of puparia yield 1,000,000 parasites. Improved technique has increased the output ten times without increasing the cost.

Technique employed in the liberation of S. glossinae.

It was decided that by far the best method of distributing the parasite was to deposit the parasitised puparia of *Chrysomya* in the tsetse's breeding-places.

The area chosen for the experiment is a stretch of six miles along the base of the escarpment, running through the lower fringe of the *Brachystegia microphylla* woods. It will be remembered that this area is the true habitat and is believed to afford the key to the local fly problem; puparia can be found in large numbers in these woods. If the fly could be exterminated in the habitat, it is very probable that it would die out in the plains.

It was decided that parasites should only be liberated along the lower fringe of the *Brachystegia* wooding, as it was believed that the prevailing easterly wind would disseminate the insect up the slopes of the escarpment. Another point in favour of this area is the poor grass growth which precludes fierce fires. As has already been shown the tsetse can fly ahead of the flames and escape, but *S. glossinae* with its weak flight must perish in large numbers unless there are abundant rock-breeding sites to act as shelters. The site chosen for the experiment appeared ideal from the parasite's point of view.

In 1928 and 1929 out of 1,550 puparia collected from the fly-belt not a single emergence of *S. glossinae* was recorded. Prior to the experiment, out of 11,000 cases collected from the site proposed for the liberation only 0.7% showed small emergence holes similar to those made by *S. glossinae*. During the earlier stages of the experiment 60,000 cases were examined; it was hoped that the progress made by *S. glossinae* could be gauged by the percentage of cases that showed the parasite's emergence holes; this would have been a more satisfactory method than that of having to remove full puparia, which decreases the material at the insect's disposal.

Unfortunately it was eventually decided that examination of the cases gave data of doubtful value. Many of the small, round emergence holes are made in the anterior end of the puparium, and it is this end that tends to break off and disintegrate. The posterior half of puparial cases is much stronger. It was felt that many parasites might have emerged from cases that were only represented by the posterior portion, so that a very conservative estimate was being obtained; collections of sound puparia confirmed this opinion. Then again, some of the probable emergence holes were doubtful, being rather bigger than anything obtained when breeding *S. glossinae* in the laboratory. It was concluded that the collection of cases gave results of too doubtful a value to be of much scientific worth.

The first liberation was made in December 1930; the parasitised blowfly puparia were placed on the floor of the breeding-site, and were left until such time as *S. glossinae* emerged. It was found that 100% of the puparia were devoured by mice, ants and other predators.

The next method employed was to take pithless sections of bamboo into which parasitised puparia were inserted, the ends being blocked with plugs of clay. Holes were bored in the walls of the tubes in order to allow of the emergence of the parasite, whilst precluding the ravages of mice and cockroaches. This method was a modification of that described by Lamborn (1925), who pointed each section at one end, so that it could be stuck into the ground. This was not done, because there is rarely enough soil in these rocky hills for that purpose. The method described was used for the March liberation, but the emergence holes had been bored too large and 60% of the puparia were devoured by small predators.

From April until August 1931 the bamboo tubes were used; the emergence holes were made about 0.75 mm. in diameter, which just enables the parasite to escape, yet thwarts the endeavours of the predators that are seeking an entry. During this period 40% of the puparia were destroyed by insects. The bamboo tubes were not satisfactory for the following reasons:—White ants attacked the wood with rapidity

and in a few days had exposed the puparia; 25% of the loss was caused by these insects. The most severe damage was done by a "stink" ant of the genus *Crematogaster* (subgenus *Sphaacrocrema*); this predator accounted for 50% of the losses incurred. It would enter the tubes at the ends, the clay plugs affording no obstacle to its depredations. The insect is small, and if the emergence holes are bored slightly bigger than the specification given above, it can readily make an entry.

Subsequently two thousand Royal Vinolia shaving stick tins were obtained through the courtesy of the Vinolia Company. These tins are admirably suited to the purpose; they are made of a soft, light, rustless metal, defy the attacks of white ants, and do not deteriorate through the weather. Small holes of the exact dimensions can be pierced in them with a pin. Since the arrival of these tins the depredations of the predators have been reduced to negligible proportions, as the total loss due to this cause has been reduced to 3.5%; an occasional ant finds a hole that is slightly too large, and manages to squeeze itself in, but predators have now ceased to be of any practical importance.

TABLE XX.
The Liberation of Syntomosphyrum glossinae.

Month	Estimate of the possible emergence	Estimate of the real emergence	Method of liberation
Dec. 1930	50,726	0	Placed loose in breeding sites
Feb. 1931	499,846	0	" " " " "
March	1,064,502	422,345	Bamboo tubes; large holes
April	557,216	473,682	" " 0.75 mm. holes
May	740,040	191,876	" " " "
June-July	429,240	291,270	" " " "
Aug.-Sept.	545,550	111,908	" " " "
Total	3,887,120	1,491,081	62% lost through predators
Sept.-Oct.	524,722	475,900	Tins; 0.75 mm. holes
Oct.-Nov.	395,163	498,658	"
Nov.-Dec.	1,913,784	1,780,655	"
Dec.	2,505,006	1,988,658	"
Jan. 1932	1,816,080	2,032,313	"
Feb.	1,682,504	1,612,485	"
March	2,066,384	1,942,420	"
April	1,611,232	1,476,944	"
May	888,584	1,136,894	"
Total	13,403,459	12,944,927	3.5% lost through predators

It has already been mentioned that out of those parasitised puparia that are ready to be liberated, some are kept back in the laboratory so that the percentage of parasitism and the average number of emergences from each puparium can be obtained.

From these two factors an estimate of the number of parasites bred out in that generation is available. In addition, when the tins are collected from the bush their puparia cases are emptied into a box, and one thousand are taken out at random. These are dissected, and a figure is obtained of the number that successfully avoided the predators and emerged. There is no difficulty in detecting those puparia that have produced parasites, as apart from the small emergence hole, dissection displays the "pupal mat" that is left by the parasites. This mat is very conspicuous owing to the iridescence of the minute pupal cases. Having found the percentage of parasitism, and knowing the average number of parasites per puparium from the laboratory control, an estimate is readily obtained of the total number of *S. glossinae* that have successfully escaped the predators and emerged.

In the second column of Table XX is given an approximate estimate of the number of parasites that would have emerged in the bush had it not been for predators; this estimate is based on the two factors obtained from the laboratory controls.

In the third column of the Table is given the approximate estimate of the true emergence in the bush, when the depredations of the predators are taken into account; the percentage of parasitism upon which this figure is based is obtained from the one thousand puparial cases which were exposed in the breeding sites, and afterwards re-collected and dissected. It will be seen that in the period when tins were not employed 62% of the possible emergences were destroyed in their puparia by predators. After the introduction of tins only 3.5% were lost.

It may be remarked that in one or two batches in the latter period the possible emergence is less than the actual emergence. This apparent anomaly is due to the fact that on those occasions predators destroyed hardly any puparia. The difference in the two estimates is due to the fact that the percentage of parasitism was obtained from the 270 laboratory control puparia in column 2, and from the 1,000 puparia re-collected and dissected in column 3; the factor was obtained in each case from a different source of data. The estimate of real emergence (column 3) should be the most accurate, since the percentage of parasitism is based upon a far greater number of dissections.

Cost of mass liberation of S. glossinae.

Since cost is always bound to be the most important consideration in any possible method for the destruction of *G. morsitans*, it is considered desirable to mention this subject.

The greatest point in favour of this parasite is that should it be successful it can be bred and liberated at an extremely low cost. No other method of destroying *G. morsitans* could be cheaper than biological control in which *S. glossinae* is used; but there is no point in giving detailed costs, as prices vary from one part of Africa to another. In order to breed two million parasites a month the initial outlay required consists of the twelve breeding boxes, which any carpenter can make cheaply, and of the grass-roofed hut for housing the boxes. Despite the inaccessibility of Kikori, the initial outlay amounted to only £19. The monthly expenditure consists of the meat and the wages of the laboratory boys. Only twenty hens are required to produce 60,000 puparia, so that in places where four or five chickens can be bought for a shilling the cost is negligible. The necessary staff consists of one good boy who can read and write, and of three children to help him collect the blowfly puparia; this staff is free every afternoon for other work, and can be employed elsewhere for the week between the batches.

The only initial outlay for the liberation consists of the shaving-soap tins. Owing to the courtesy of Messrs. Lever Bros. Ltd. 2,000 tins, including freight, cost only £10; but further consignments would have to be purchased from the trade and would cost about £15. Only 1,000 tins are used at a time, the remainder being kept to replenish

losses. During eight months 320 tins have been lost, but probably many of these will be found when the grass is burnt. Even at this rate of loss, the 1,000 reserve tins will not be expended for two years. On the day of liberation five porters are needed to carry the tins, and about eight experienced fly-boys to place each tin in a suitable breeding-site. The same number of natives will be required a fortnight later, for the day upon which the tins are re-collected.

The European in charge will find that the work occupies very little of his time, since once the laboratory boy has been trained the technique becomes a matter of routine. It will be realised from these few details how extremely cheap is the breeding and liberation of *S. glossinae*.

Results of this experiment in biological control.

Up till early September 1931 the liberation of *S. glossinae* can be said to have hardly begun, owing to the tremendous losses due to predators. During this preliminary period the liberation extended along the foot of the escarpment for four and half miles and for a distance of about half a mile within the lower fringe of the true habitat. There was such a delay in the arrival of the tins from England that it was decided to reduce the length of the chosen site to one and a half miles; up till early September 1931 only 750,000 parasites had been successfully liberated in this smaller area over a period of nine months. Hence the real mass liberation did not start until October 1931. The progress made by *S. glossinae* is gauged by the number of living puparia which this species has parasitised, from those collected along three different puparial rounds passing through the habitat.

Firstly there is Round A, which runs along the lower portion of the liberation area; here, the breeding is confined to rock sites. Then there is Round B, which passes through the upper portion of the liberation area and includes some fine log breeding-sites. Round C runs parallel with B, and is about half a mile further up the hills than the nearest portion of the liberation area. This round was made in order to demonstrate the spreading powers of the parasite. The test was severe, as a small open valley, in which there is no breeding, separates Round C from B.

In addition there is the Control Round, which is about a mile and a half further down the escarpment and separated from the liberation area by two large cultivated valleys that must form very adequate barriers to the passage of *S. glossinae*. This Round passes through the same *Brachystegia microphylla* community as is found in the liberation area. Lastly, there is the *Berlinia* Round which is down in the plains, and is about seven miles south of the liberation site. This Round is in the nature of a second control, even though it passes through a different vegetation community.

The progress made by *S. glossinae* in establishing itself is given in Table XXI. It will be seen that in 1928 and 1929 *S. glossinae* appeared to be absent from this fly belt; actually it was not absent, since Mr. Potts obtained several parasitised puparia, which were the ancestors of the great numbers that are now being reared every month. Suffice to say that *S. glossinae* was exceedingly scarce in the district, and none was found in the area chosen for liberation.

The next collection of puparia was made shortly after the tins had arrived, and after only 3,500,000 parasites had been liberated; 1% of the live puparia were parasitised in the liberation area (A and B). The next collection was made a month later, by which time a total of 5,500,000 parasites were believed to have successfully emerged in the area. Over 4% of the live puparia were parasitised in the lower part of the liberation site, but over 11% of those taken from the upper part yielded *S. glossinae*.

It is believed that the country tapped by Round B is more suitable to the parasite because of the log sites under which coarse humus is always found, whereas the rock sites, prevalent along Round A, have sandy floors into which the parasite cannot

burrow in search of puparia (see p. 168). Up to this time the parasite had failed to reach Round C. No further collections were made for over four months, as it was considered advisable to leave the breeding sites undisturbed.

In early June 1932 the next collection of puparia was made, by which time a total of 13,750,000 parasites had been liberated. It will be seen from the Table that only 1.4% of live puparia were parasitised along Round A, and only 2.6% along Round B. Despite these great liberations of *S. glossinae* the percentage of parasitism had fallen. Since this decrease was possibly seasonal, and since there may be a time of year when the parasite can thrive, it has been decided to continue breeding and liberating *S. glossinae* until December 1932 when a year of the mass liberations will have been completed.

TABLE XXI.
The Progress made by Syntomosphyrum glossinae.

When collected	Round	Total puparia collected	Total emergences	Percentage of live puparia parasitised	Estimate of total parasites liberated
1928 and 1929	A, B, C, and Control	783	683	0.0	0
	Berlinia	451	343	0.0	
Late Dec. 1931	A and B	254	193	1.0	3½ millions by early December 1931
	C	222	202	0.0	
	Control	196	156	0.0	
	Berlinia	30	24	0.0	
Late Jan. 1932	A	50	46	4.4	5½ millions by early January 1932
	B	171	149	11.3	
	C	66	35	0.0	
	Control	128	96	0.0	
	Berlinia	223	173	0.0	
Early June 1932	A	124	73	1.4	13¾ millions by late May 1932
	B	489	312	2.6	
	C	174	165	0.0	
	Control	453	422	0.0	
	Berlinia	106	89	0.0	

It can be concluded that up till July 1932 the parasites had made but little advance towards establishing themselves within the area. This can probably be accounted for by the inability of *S. glossinae* to penetrate sandy soils, such as are found under the rock sites, which form a feature of the breeding areas of this fly-belt.

The prospects of *S. glossinae* being a success locally would appear exceedingly small. However, before this insect can be dismissed from the list of parasites having a possible economic value, it remains to give it a trial in an area where tsetse breed

solely in humus. Such conditions have been found on an island in Lake Victoria, off Musoma. This island is infested by *G. palpalis*. The writer hopes that circumstances will permit of his undertaking a mass liberation of *S. glossinae* upon this island at some future date.

V. TRAPS FOR PUPARIA.

Two types of trap have been constructed ; one has been made of boards and is intended to simulate a natural rock site, and the other is made out of a tree, and is intended to imitate a natural log breeding-site. Each will be dealt with separately. Mr. Heard was attached to this station for the first month of the investigation and proffered many valuable suggestions which were incorporated in the traps.

1. Board Traps.

The writer has frequently noticed that photographs of hill-sides having rocky outcrops invariably show up the tsetse breeding-sites as black masses. Since *G. morsitans* hunts by sight, it was argued that pregnant females may be attracted by the black cavernous appearance presented by the darkness under an outcropping slab of rock. It was decided to make artificial sites that by their bulk and obviousness would eclipse the natural breeding-places, and would attract all females to extrude their larvae within the traps. It has been found that the natural rock breeding-sites are not evenly distributed throughout the bush, as was first supposed, but that they are aggregated into what the natives call "fortresses." At first sight there appears to be a continuous line of rock sites along the foothills of the escarpment. Closer inspection reveals the fact that the majority of rocks are quite unsuited to the females' needs. Every quarter of a mile or so there are, however, groups of rocks whose outcrop is ideal for the purpose. A large "fortress" covers only a small area, but within its limits the number of breeding sites is innumerable. Only six large "fortresses" and three small are known to exist in a stretch of six miles along the escarpment.

Should it be possible to make the pregnant females forsake the innumerable breeding-sites that compose a "fortress" for a single artificial one, a great concentration of puparia would have been achieved. This aggregation of puparia could then either be destroyed by hand-collecting, or be put to a more economical use, such as being strongly parasitised with *Syntomosphyrum glossinae*, and left to propagate the parasite. In this way a puparium deposited in the trap would be killed by *S. glossinae* and at the same time afford a food supply for the parasite's numerous offspring.

Two types of board trap were devised :—

Trap A.

This is the simplest design, which is supposed to represent a giant outcropping slab of rock. It consists of a tray filled with sand, representing the floor of a natural site ; to the back of it is hinged a sloping roof that projects beyond the front of the tray ; the inside of the trap is painted black. The floor is 3ft. by 4ft., and the roof 3½ft. by 4ft. To flies approaching from the front, the trap appears as a very large, dark, and conspicuous breeding-site. At Mr. Heard's suggestion a partition was fixed in the centre of the floor, so that flies approaching from one side would not be able to see through the trap, but would also be attracted by the darkness of the interior. Dry leaves of *B. microphylla* were glued to the outside of the roof, so that from the back it is hard to detect the trap, because it blends in with the surrounding rocks.

The trap was placed in position on 13th August 1931 on the top of a rocky hill. It faces N.E., as does the natural outcrop, and seen from below dominates the



Fig. 1. Board Trap A.



Fig. 2. Board Trap B

Puparial Traps for Tsetse Flies.

surrounding sites (see Plate iv, fig. 1). Among the rocks shown in the foreground are many suitable breeding-places, but it will be noticed that the trap is very much more conspicuous than any single site.

Trap B.

This trap is of a more complex type. It is not designed to mimic a breeding-site, but to accentuate its natural characteristics, *i.e.*, a conspicuous black mass that affords deep shadow inside.

Trap A, in common with even the best natural sites, can only be seen by flies approaching through an arc of 180°, whereas Trap B presents its attractive characteristics to fly arriving from any direction.

It consists of a tray 6 ft. long and 4 ft. wide, which is divided by a central, vertical partition. From the top of the partition a roof slopes down over each half of the tray, and ends about a foot from the ground. The sides are partly closed in with sacking (see Plate iv, fig. 2). It will be seen that the roof, which is painted black, and the long line of shadow that marks the narrow opening, present the appearance of a black cavernous mass from each end. Owing to the shadow, the open parts of the side appear as two black triangles that strongly contrast with the pale sacking.

This trap was placed on the brow of a rocky hill on 17th August 1931, and can be seen from over 100 yards from below; it completely dominates the small hill, and is also conspicuous from other directions.

Results given by traps.

These traps have been working for nine months from mid-August 1931 until mid-June 1932. During this period there have only been 7 deposits in trap A, and 6 in trap B.

Clearly these artificial breeding-places, intended to accentuate the characteristics of the natural rock sites, are a complete failure.

2. Log Traps.

Lamborn (1916) constructed a number of artificial breeding-sites by felling large trees in suitable places, and by making the soil beneath them friable and generally attractive. He destroyed the natural sites in the neighbourhood, and found that his artificial breeding-places were more attractive than the natural sites. His investigation came to a premature ending, owing to the War, but he concluded that artificial breeding-places of this type might be of value in clearing fly from the vicinity of roads and railways.

It has been found at Kikori that a suitable log often yields many puparia, whereas individual rock sites rarely give more than two or three. Should logs be more attractive than rock sites, there would clearly be possibilities in felling trees in the rock "fortresses."

The question arose as to how the puparia deposited beneath the logs could be destroyed; hand-collecting was obviously both impracticable and inefficient. It was then decided to investigate the possibility of the sun as a destructive agent of tsetse puparia buried beneath the surface of the soil.

Experiments upon the effect of the sun at different seasons upon puparia buried at different depths.

A number of experiments were carried out in which tsetse puparia were exposed for a day on the surface of the soil with a maximum recording thermometer. It was found that puparia could survive a maximum temperature of 111°F. but not 113°F.; hence it was concluded that the death point is approximately 112°F. Since the duration for which the puparia were subjected to these maximum temperatures was not

taken into account, the data have no precise scientific value; they showed, however, that if the sun temperature at the surface of the soil reached 113 F., then all the tsetse in pupation would be destroyed.

The next step was to discover to what depths the sun could raise the soil temperature to the level required to destroy the puparia, taking into account the season of the year.

1. Exposure during the cooler part of the year (late July).

Over a period of five days four batches of 50 puparia were exposed to the following conditions:—One batch was placed on the surface of the soil, and the other three batches were buried under half, one, and two inches of earth. A fifth batch was kept in the laboratory as a control. A maximum recording thermometer was placed with each batch at the same level as the puparia. At the end of the fifth day the puparia were removed, placed in the laboratory, and the subsequent emergences recorded. The results are given in Table XXII.

TABLE XXII.

Sky overcast for Initial Exposure at Dawn during the Cold Weather.

Exposure	Max. temp. for period (F.)	Mean max. temp. for period (F.)	Emergences during exposure	Emergences after exposure		Total emergence % (parasites included)
				Tsetse	Thyridanthrax	
Surface ...	140.50°	130.00°	5	0	0	10
$\frac{1}{2}$ inch ...	133.50°	121.50°	4	0	0	8
1 inch ...	118.00°	110.50°	4	0	3	14
2 inches ...	110.00°	103.00°	10	30	3	86
Controls ...	76.00°	74.00°	5	33	4	84

The highest maximum temperature recorded within the five days is given in column 2, and the mean of the maximums for each of the five days is given in column 3. The emergences from the puparia during the period of exposure are given in column 4; the emergences for the period following the exposure are shown in column 5, which is subdivided into the emergences of *G. morsitans* and the emergences of *Thyridanthrax*, because the tsetse has been found to be less heat-resistant than these parasites. During the exposure period the daily emergences were recorded.

The puparia were exposed at dawn on an overcast morning; when the sun came out and the soil started to warm up, the heat caused an acceleration in emergence. All the emergences down to the one inch depth, recorded in column 4, as having taken place during the five days exposure period, actually took place before 11 a.m. on the first day. A separate experiment has shown that unless the initial exposure is made in hot sun near mid-day quite a number of tsetse will escape the lethal effects of the sun. A comparison with the laboratory controls shows that the number of emergences on the first day is much greater with exposed puparia; a definite acceleration takes place, the emergence being advanced by as much as four days. Hence the figures for exposures from the surface down to one inch, given in column 4 and in the last column, do not mean that flies survived the first day's maximum temperature; they are all based on the initial emergence that took place during the first few hours of the exposure.

It will be seen from the emergences *after* the five days of exposure (column 5), that all tsetse down to one inch depth were unable to survive the maximum temperature of 118°F. recorded at this level; however, the *Thyridanthrax* were unaffected. At two inches depth puparia of *G. morsitans* were not killed by the maximum temperature of 110°F.; they were as healthy as the controls.

2. Exposure during a warmer part of the year.

A similar experiment was carried out in the warmer weather of September. The puparia were not exposed until mid-day, in order to prevent the escape of a few tsetse owing to accelerated emergence. The results are given in Table XXIII, which is identical with the previous Table with the one exception that a depth of one and half inches was substituted for two inches.

TABLE XXIII.

Exposure	Max. temp. for period (F.)	Mean max. temp. for period (F.)	Emergences during exposure	Emergences after exposure		Total emergence % (parasites included)
				Tsetse	Thyridanthrax	
Surface ...	154.50°	142.00°	0	0	0	0
$\frac{1}{2}$ inch ...	147.00°	135.00°	0	0	0	0
1 inch ...	125.50°	120.00°	0	0	0	0
1½ inch ...	119.00°	112.00°	0	0	2	4
Controls ...	76.00°	74.00°	5	33	4	84

It will be seen from column 5 that all puparia of *G. morsitans* were killed down to a depth of one and a-half inches, being unable to withstand a maximum temperature of 119°F.; however, *Thyridanthrax* was unaffected. Owing to the initial exposure being made in hot sun near mid-day there were no emergences during the five days (column 4); all puparia were probably killed very shortly after exposure.

Many further experiments have proved that, except during the rains and cold weather, an exposure of one day is quite sufficient to kill the tsetse puparia. The maximum temperature at one and a half inches during a day is usually about 118°F., and as tsetse puparia are killed at about 112°F., there is quite a margin of safety.

3. Exposure during the rains.

The following experiment was designed to show how many days' exposure is required, during the rains, to kill all the tsetse puparia buried under one inch of soil that is completely water-logged at the commencement of the period.

In late February four batches of fifteen puparia were buried under one inch of water-logged soil. On each day, out of four, one batch was removed to the laboratory, the maximum temperature having been recorded; 25 puparia were kept in the laboratory as controls.

The results are given in Table XXIV.

Comparison of the third and last columns shows that accelerated emergence tended to take place, since only one tsetse emerged from the controls during the exposure period. It will be seen in column 4 that tsetse survived a maximum temperature of 111°F., but succumbed to 113.25°F., whereas *Thyridanthrax* survived 118°F. The control puparia gave a total emergence of 85%, 8% of which were *Thyridanthrax*.

From these results it is concluded that during the rains at least three consecutive fine days are required to destroy the tsetse puparia; even if these occur a few fly will successfully emerge in the first two days, when the soil is so wet that high temperatures are impossible. The conditions were perhaps rather unnaturally severe, as the soil was saturated at the commencement of the experiment, whereas under the shelter of a log the earth would tend to be drier than elsewhere.

TABLE XXIV.

Four batches of puparia buried under one inch of water-logged soil.

Duration of exposure	Max. temp. (F.)	Emergences during exposure	Emergences after exposure		Total emergence % (parasites included)	Control emergences during exposure
			Tsetse	Thyridanthrax		
1 day ...	98.00°	2	9	2	87	0
2 days ...	111.00°	1	9	0	67	0
3 days ...	113.25°	1	0	1	13	1
4 days ...	118.00°	0	0	1	7	0

4. The resistance of the puparia of *S. glossinae* to the sun.

Owing to the relatively high temperatures which *Thyridanthrax* could survive, it appeared important to ascertain whether *S. glossinae* was capable of a similar resistance to the effect of the sun.

Accordingly, seven batches of ten infected puparia were placed on the surface of the soil until seven different maximum temperatures, ranging between 109 and 120°F., had been recorded. The subsequent emergences were noted, and it was found that *S. glossinae* could withstand a maximum temperature of 111°F., but not 113°F.; it would appear that the upper fatal limit for the immature stages of both *G. morsitans* and *S. glossinae* is about 112°F. The exposure was made when the parasites were adjudged to have completed half their life-cycle.

Conclusions upon the lethal effects of the sun upon puparia.

The results from these small experiments were considered to be very promising. It was concluded that the exposure, during the dry season, of the breeding-sites of *G. morsitans* to the mid-day sun would result in the destruction of all tsetse puparia down to a depth of at least one and a-half inches. Since puparia are rarely found at depths exceeding half to one inch, it was clear that very few puparia would ever escape destruction. The same holds good for the cold season.

During the rains results were not quite so satisfactory. Should it be possible to obtain three consecutive dry days, the sun would probably succeed in destroying the puparia; however, there is a distinct element of luck in attempting to forecast such a dry period in the heaviest part of the rains, even though three dry days are not an unusual event. When the rains have broken and are at their heaviest, it is wiser to expose the breeding-sites to the effect of the water-logging of the soil. It will be remembered that puparia cannot survive more than four days of such conditions (see p. 114).

Results suggest that *G. morsitans* and *S. glossinae* cannot survive a maximum soil temperature of 113°F.; but that *Thyridanthrax* can remain unaffected by a soil

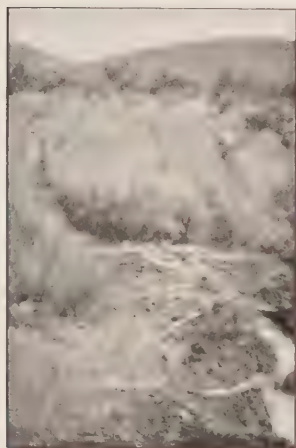


Fig. 1. Imitation Game Paths leading to a Pool.

(See page 147.)



Fig. 2. A Log Trap 25 feet long.



Fig. 3. A simple, unscreened Trap.



Fig. 4. A Bark-screened Trap



Fig. 5. A Rock-screened Trap.



Fig. 6. Trap advertised by a Hessian-covered Frame.

Puparial Traps for Tsetse Flies.

temperature of 119°F. The fact that these parasites can withstand greater temperatures than *G. morsitans* is important, as it will mean that when all tsetse and *S. glossinae* are destroyed by the sun, a few *Thyridanthrax* will survive. Thus one will tend to increase the proportion of these parasites in the bush.

Description of the log traps.

Since it had been decided to use the heat of the sun to destroy the puparia of *G. morsitans* it was obviously necessary to be able to roll the log traps from the breeding sites which they sheltered, in order that the lightly buried puparia might be exposed to the requisite high temperatures.

Mr. Heard devised the following simple, but very efficient, method by which the largest logs can be shifted by three boys:—

A tree is felled and its top-hammer removed, leaving a suitable log. Two straight boughs are selected from the crown, and one is placed at each end of the log and at right angles to it; the log is thus mounted on rollers, and if fairly small can be shifted with ease by one boy. A log 25½ ft. long with a mean circumference of 45 inches has been mounted in this fashion, and can be rolled by three boys (Plate v, fig. 2).

The cheapness with which a trap can be made depends largely upon the care with which the tree is chosen. It is essential that the trunk of the tree be straight; a crooked, twisting tree is useless, as it will not roll easily, owing to the excrescences catching on the surface of the ground. *Albizzia versicolor*, *Berlinia globiflora*, *Boscia* sp., and *Brachystegia microphylla*, are the species that have been generally employed, as straight growth is common among these trees. Another important point is not to choose a tree that has an abnormally large circumference at its base. Such a tree takes a very long time to fell, and makes no more effective a trap than a smaller tree whose girth is about 45 inches. Trees which support a very large top-hammer should be avoided, as considerable time is wasted in cleaning up the branches which form the crown.

When it becomes obvious in which direction the tree will fall the rollers should be placed in position, for if the tree falls upon them, the necessity is removed of lifting each end of the log and inserting a pole. When the tree has fallen the branches should, if possible, be cut off at the point where they leave the crown, as a spatulate head to the log gives a shelter that is much favoured by the pregnant females. Should it be realised that the head of the log will become too bulky to permit of rolling, then no attempt should be made to retain the spatulate head, the trunk being cut off below the crown. The grass is removed from beneath the log and the earth is broken up so as to afford a bed composed of loose, friable soil.

Attempts were made to train boys to cut down trees with a cross-cut saw; this was soon given up as the average native works far better with an axe. Four men with axes can complete a trap in 45 minutes if the log is about 15 feet long and has a mean circumference of 45 inches; a log only 9 ft. long and having the same girth will answer the purpose just as well.

The first experiment was started in September 1931, when twelve log traps were made in *B. microphylla* wooding which supported a relatively low fly density. In all 28 traps have been made in different parts of the bush. No attempt has ever been made to destroy the natural breeding-sites in order to encourage deposition within the traps. It was considered essential to test these artificial breeding-sites under the most severe conditions obtainable; for this reason all experiments have been carried out in the true habitats where natural sites are abundant.

For each trap the following data have been kept:—(1) Time taken to set up, (2) mean circumference of log, (3) length of log, (4) mean height above ground, (5) orientation.

The first three items have already been dealt with and refer to the cost of production. Huge trees are no more attractive than small ones, but they cost much more to fell.

The mean height of the log above the ground is regulated by the size of the rollers. A log having an abnormally large circumference of from 43 to 58 inches should be raised about 6 inches off the ground, but the smaller and more generally used logs need only be raised about 3 to 4 inches. A general rule is that the smaller the log the nearer to the ground it should be; a small log raised too far above the surface does not produce sufficient shelter to be attractive to the female.

The direction which the trap faces appears to be a matter of no importance.

A question arises as to whether the top-hamper should be converted into small subsidiary traps, or whether it should be cut up and stacked so that the larger branches cannot act as breeding-sites. It was thought that possibly the addition of a number of small traps, made out of suitable boughs cut from the crown, would increase the total deposit.

Accordingly two log traps were supplemented with a few boughs from the top-hamper, so that in each case there was the main log and four or five boughs in the neighbourhood, each of which could form a breeding-place. Two other trees were felled in the vicinity as controls, and each of these consisted of the main log only; the top-hamper in each case was rendered useless as a breeding-site, the boughs being cut up and stacked against trees.

During the first seven months the two traps supplemented by subsidiary logs from the top-hamper gave a total of 179 deposits, whereas the other two traps, each composed of the main log only, gave 185 deposits. It was concluded from these results that the conversion of the top-hamper into additional small traps did not increase the total yield, it merely tended to spread it; had there been no subsidiary traps the whole deposit would probably have been concentrated under the main log. Normally it is best to leave the crown of the tree intact and not to bother about its utilisation. All possible breeding-places under branches of the crown should be stuffed up with twigs or grass, so as to render them unattractive.

* * * * *

The simplest type of trap has now been described; it consists of a log mounted upon two rollers over a roughly prepared soil bed (Plate v, fig. 3). It has been found that a few of these traps have been a great success, but that others remained useless until some alterations were made. The evolution of the final trap will be described by means of a few examples:—

Trap 7 is a large rotting tree which for four years has been a magnificent natural log site, far superior to any other log in the neighbourhood. This fallen tree was raised over its natural soil bed upon rollers, and was thus converted into a trap.

Trap 8 was made within 20 yards of No. 7; it is rather smaller, but otherwise has a strong superficial resemblance to the old log. Seventy days after construction both traps were re-visited. The old log yielded 40 deposits, whereas No. 8 gave only 3. Clearly mounting No. 7 upon rollers had not destroyed its attractiveness.

At this time it was believed that the nature of the soil bed under the old log, composed as it was of decaying bark, frass from boring beetle larvae, etc., accounted for its superior attractiveness; to test this hypothesis the log was rolled two yards from its original bed, until it lay above ordinary soil which was broken up, as is customary for all traps. Two months later the site was re-visited; the old log gave 30 deposits, and the control, No. 8, gave none. Clearly shifting No. 7 from its old soil bed had not destroyed its attractiveness; there would appear to be no curious qualities about the soil in an old site, which can hold a particular lure for the larva-depositing female.

It was noticed that No. 7 was very shut in by grass, but that No. 8 was rather open; this suggested that the new log might be made more attractive if its bed was less exposed. It had also been observed that remarkably attractive log sites were often characterised by bark that had fallen off the log in the process of decay, and which lay along each side partly screening portions of the bed from the rays of the early morning and late afternoon sun. This observation suggested the possible value of stripping the bark from No. 8 and pegging it along the sides, leaving occasional apertures, which would appear as black windows. The log was treated in this fashion (Plate v, fig. 4).

Remembering the results of the experiments upon the lethal effect of the sun upon puparia, it was argued that the pregnant female might be influenced by the stimulus of gloom, which might produce the reflex action of extrusion. Since all insects are guided by instinct in their choice of foods and breeding-places, it is likely that the female tsetse will be influenced in her normal choice of a breeding-site, by the sufficiency of shade from the sun's rays.

Only one month later these traps were re-visited; the old log gave 14 deposits, and Tree 8 gave 10; it appeared that at last the new log was going to enter into competition with the old. No alterations were made. Forty-seven days later No. 7 gave 35 deposits, and No. 8 gave 18—competition continued. The next examination, two months later, showed that 33 deposits had been made under the old log, but that there were 39 deposits under No. 8. At last the new log had become more attractive than the old; its superiority still continues.

This screening of a log trap has now become a matter of routine. It has been found that even though a few traps give excellent results without, because they are already densely screened by grass, yet the majority need this addition to make them attractive. If there are abundant slabs of rock in the vicinity of a trap, these will produce the required shelter if laid against the log (Plate V, fig. 5); traps screened in this fashion give excellent results.

At first the ground surrounding some of the traps was well weeded, it being felt that good visibility would probably play an important part in attracting pregnant females; this was soon given up as it was found that the traps in unweeded sites became more attractive as the grass grew thicker, unlike traps from around which the grass had been removed. It is not suggested that the grass should be left untouched in places where it grows luxuriously, but at Kikori the grass in the habitat rarely grows more than three feet in height. In long-grass country it would probably be better to weed the grass from a small patch on each side of the log so as to enable the tsetse to enter the dark tunnel that runs underneath the length of the trap.

The curious phenomenon that certain natural log sites are not always attractive throughout the year may be in part due to this question of shelter from the sun's rays. Sites that have been shielded by grass during the rains may become unsuitable after the fires, owing to the destruction of their shade. Other logs, owing to their orientation, may only be able to produce sufficient shade at certain times of the year, dependant upon the seasonal variations in the position of the mid-day sun.

It has already been shown that, provided the soil is friable, there would appear to be no special preference on the part of the female for the type of humus that is formed beneath a rotting tree. On the other hand if water gains access to a clayey soil underneath a trap, the surface of the bed becomes hard and no puparia are found. In friable soils the earth may be very damp, but puparia are still obtained. If a small ditch is dug round the trap when its soil-surface has become hard, the increased drainage will be found to result in increased yield in the following months.

Trap No. 2 is a good example of the effect of drainage. During the first four months this trap gave an average deposit of only 0.57 puparia in ten days; it was then weeded, and in the following month the figure fell to 0.33. The trap was then

drained, and after forty-seven days the figure had risen to 1·80, and after a further two months, comprising the heaviest part of the rains, the average deposit of puparia, in ten days, had risen to 9·30. Admittedly some of this increase may be due to the growth of fresh grass, but the soil never became caked and hard again.

It is impossible to say whether the female can detect suitable, friable soil; she may have no powers of differentiation and extrude her larva on hard soil, in which case her offspring will be unable to burrow and will succumb to predators. Thus it is possible that larvae are extruded within traps having hard soil, even though no puparia are found beneath them. The writer rather tends to the view that the female is mainly influenced by the degree of shelter in a breeding site, to the exclusion of all else. A trap has been made in which the grass was left beneath the log, no bed of friable earth being prepared. Shade was provided by screens of bark, and eleven deposits were made; these puparia were deep down at the base of the grass stems, but had failed to penetrate the soil.

Another interesting point that has come to light is that there are places within the true habitat where good breeding-sites abound, but where puparia are hardly ever found; traps placed in such localities rarely produce a yield. One such site is round the camp, and another at the bottom of the hills. The yield would appear to increase as one ascends the hills, but much more data are required before any conclusions can be reached.

Another modification was tried on the suggestion of Mr. Swynnerton. Hessian has been found to be attractive to fly when used on traps or dummies (Harris 1930), or when carried in the form of screens by fly-boys engaged in hand-catching (recent work by Mr. Lloyd at Shinyanga). Accordingly a log was advertised by means of a 12ft. by 3ft. Hessian screen fixed above it (Plate V, fig. 6). If anything, the screen was a deterrent to deposition of larvae by females, as this is one of the worst traps. The result is not really very surprising, for Hessian has always been found attractive to food-hunting tsetse, whereas the log traps are intended to attract the pregnant females only. A fly that is urgently hunting for a suitable site in which to extrude her larva is hardly likely to be attracted by anything suggestive of game.

Log traps in competition with natural sites.

As already mentioned, all traps are in competition with natural sites, but several traps have been deliberately made in places where natural sites are abnormally numerous. For example Trap No. 18 was made within a few yards of two exceptionally good natural log sites, the first of which produced 8 puparia and 61 cases, and the second 43 puparia and 300 cases.

Forty-one days after the construction of the trap it was re-visited and gave only 6 puparia, whereas the first natural site gave 7 cases, and the second one 22 puparia and 44 cases. Clearly the trap could not compete with established log sites. The second site that was so productive had piles of bark lying on each side of the log; these strips of bark had fallen off the log some years before and lay where they had fallen, producing excellent shelter from the sun. This bark was taken and placed round the trap, the bark of which was still too green to remove; with this one exception the second natural site was left undisturbed.

Two months later the area was re-visited. The trap yielded 45 deposits, the first natural site 53 deposits, and the second one only 8. Clearly the removal of these few strips of bark had completely destroyed the superior attractive powers of the second natural site, causing the tsetse to transfer their favour to the remaining site and to the log trap.

Many other similar experiments have been carried out. In Table XXV is given a summary of the results obtained from two other traps placed among attractive natural sites.

It will be seen that the log trap is vastly superior to rock sites, and can even cause them to be deserted by the fly; but log sites, though often less attractive than the trap, can still continue to yield puparia. From a practical point of view this is of no importance whatsoever, as every natural log site can be converted into a trap by placing a roller under each end; naturally this is far cheaper than having to fell a tree. In practice one would never fell a tree in places where there are logs that can be so readily converted into traps. Log traps have only been placed amid natural log sites in order to prove that these artificial constructions are as good as the best natural sites, if not better.

TABLE XXV.

Log Traps in competition with Natural Sites.

Period in months	Total deposits			Description of competitive sites
	In trap	In rock sites	In log sites	
10	173	4	—	5 good rock sites
5½	110	0	86	6 good rock sites 4 good log sites

Cost of log traps.

Four boys in forty-five minutes can fell a suitable tree and convert it into a trap; they can construct eight traps in a day without any difficulty. If the rate of pay is sixpence a day, each new trap can be made for threepence. At the same rate of pay, when natural log sites are converted into traps each will cost a penny.

No estimate can be given for rolling the traps, but a gang of three boys should be able to roll a great number in a day. During the cooler months of the year, when the pupal period is longer, traps are only rolled every forty days, but in the hot weather they are rolled every twenty-eight days.

There is no reason why a trap should not last for years, taking a steady toll of the tsetse puparia month by month. Clearly this method for the destruction of tsetse puparia is exceedingly cheap.

Results given by log traps.

A few results are given in Table XXVI showing the increased yield due to constant modifications in the design. It has been impossible to examine the traps at regular intervals; for this reason results are given as the number of deposits in ten days—a unit that can be used for purposes of comparison.

It will be seen from the first half of the Table that the yield, for all the first twelve traps constructed, has risen from 11.71 deposits to 95.56 in ten days; this has been primarily due to the improvements made in each trap. It may appear that a yield of approximately 96 puparia in ten days from twelve traps is exceedingly poor; however, four of this batch of logs were constructed near the camp and have only yielded 25 deposits in ten months; hence the figure given in the Table can almost be said to reflect the yield from eight traps only. If these four traps were ignored, then eight traps would have yielded 96 deposits in ten days, an average of 12 to a trap in ten days.

When it is remembered that these traps have had to compete with dozens of natural breeding-sites in an area of only medium high fly density, the results are considered to be very satisfactory. Had the natural logs been turned into traps,

the yield would have been much greater, since competition would have been abolished, rock sites being almost incapable of attracting pregnant females when logs are provided.

In the second half of Table XXVI, the results of a more recent batch of only four traps is given; these traps embodied all the recent improvements such as bark or rock screening, ditching, and allowing the grass to grow. It will be seen that after the first examination of the original, primitive twelve traps the rate of deposition was 11.71, giving each trap an average of nearly one deposit in ten days. The four specialised traps, however, started with a deposition rate of 21.03, thus giving an average of over five deposits to a trap in ten days. For the first batch one sees a gradual improvement taking place following the evolution of the trap; for the second batch one sees the immediate establishment of a good yield.

TABLE XXVI.
Steady Improvement in Yield due to Modifications.

Combined results for 12 traps (Sept. 1931–Aug. 1932)			Combined results for 4 traps (Feb. 1932–Aug. 1932)		
Interval between examinations	Total deposit	Deposit in 10 days	Interval between examinations	Total deposit	Deposit in 10 days
70 days	82	11.71			
63 "	84	14.00			
31 "	83	27.65			
47 "	183	36.60	43 days	74	21.03
62 "	401	67.34	62 "	166	27.62
38 "	274	68.53	64 "	145	24.16
45 "	430	95.56	47 "	162	34.45
1 year	1,537	12 traps	7 months	547	4 traps

It may be argued that no account has been taken of the seasonal increase in breeding; but a few control logs that have never been improved continue throughout all months to yield very poor deposits, so that it is fair to state that this improvement is mainly due to the modifications made. All the good traps in this area of abundant competitive sites give an average deposit of from one to three puparia a day. A log is often a failure for the first month or two; possibly it is too green and new-looking, and deters the pregnant females.

A batch of six traps situated in a *Berlinia* wood in the plains has given much better results owing to the scarcity of natural breeding sites.

During the last two months of the heavy rains these six traps combined yielded only 35 deposits, despite the fact that they were drained, screened with bark, etc.; admittedly the draining was not a success, because of the flatness of the low-lying ground. During the two months that followed the rains they gave a total yield of 477 deposits; no alterations had been made in the traps. This yield was exceedingly high, giving each trap an average deposit of 1.3 puparia a day in an area where fly density for the same period was only 1.6 F.B. 100 Y., or approximately 11 tsetse to a catcher in nearly half a mile. Clearly, breeding within this low-lying habitat almost stopped during the heavy rains, but started again as soon as the ground ceased to be water-logged and the atmosphere humid.

The sudden increase in the number of puparia found within the *Berlinia* wood after the rains was not experienced in the hills. It does not represent an increase in breeding over the whole fly-belt, but rather a renewal of breeding which had probably been temporarily and locally arrested by the high humidity experienced in the plains during the wet season.

Even though the *Berlinia* wooding of the plains is classed as a true habitat because of the refuge it affords after the fires, and because breeding never entirely ceases within it, yet in its value as a home to the fly community it cannot compare with the *B. microphylla* habitats of the hills, where no similar cessation of breeding occurred during the heavy rains.

During forty-eight days in the mid-dry season these six traps in the *Berlinia* wood gave a total yield of 1,224 deposits, an average of 4.2 deposits to a trap per diem. The best trap yielded 362 puparia after these seven weeks, an average of 7.5 deposits per diem; hence this stationary trap is visited by more than seven pregnant females each day, whereas during four years only 697 pregnant females have been caught on 26 miles of fly-rounds.

This batch of six log traps cost only eighteen-pence to make, yet in seven weeks they destroyed 1,224 puparia; as there is no reason why they should not last five years, the number of puparia that could be destroyed for this initial outlay is enormous. Had one hundred traps been made in this wood at a total cost of twenty-five shillings, 20,400 puparia would theoretically have been destroyed during only seven weeks of the traps' life. One cannot compare the number of puparia taken by a log trap with the number of adult fly taken in other types of trap, as the former depend solely upon that small element—the pregnant females.

There can be little doubt that the superior success attending traps placed in the plains is due to the dearth of natural breeding-sites. In the hills there are countless rock sites, and owing to sparse grass growth and consequent poor fires, there is a great accumulation of fallen trees. In any practical experiment these logs would be converted into traps at a very low cost, and hence the main source of competition would cease to exist.

The possibilities of log traps.

The publication of these results may seem premature, since no attempt has yet been made to clear a fly-belt by means of these traps. It was decided not to withhold the results, because apart from the economic possibilities of log traps, they have been found invaluable for the production of a steady supply of puparia for use in the laboratory.

The traps concentrate the breeding activities of *G. morsitans* to a few logs which can be quickly searched by the fly-boys with a certainty of success. When boys have to be sent into the bush to hunt for puparia they have to search under hundreds of breeding-sites from most of which they get only a very few puparia. The work is laborious and the yield very variable, whereas, when using traps, as many as 356 full puparia have been taken from one log. If the competitive sites are destroyed, or converted into traps embodying the ideal features of the perfect site, many more puparia should be taken.

Log traps are also useful in throwing light upon the breeding of tsetse in relation to season, as, if the traps are unaltered, a monthly comparison of the yield demonstrates those times of year when deposition of larvae is most frequent.

Log traps employed on the large scale might clear an area of fly at the end of the long dry season. At this time fly density is very low, and probably fly longevity greatly decreased (see pp. 127–128); every puparium deposited then must be of great value to the survival of the fly community.

In the late dry season the earth is dry and the sun is very powerful, and total destruction is assured of all puparia exposed. Log traps would certainly reduce the fly numbers tremendously at this time, and might clear a small fly-belt. Owing to the lack of grass and shade, puparia tend to be concentrated in the best sheltered sites at this time of year, and deposition seems to be far less promiscuous than during the rains. If deposition could be confined and concentrated to the traps, the new generation that is required to re-establish the population after the advent of the early rains would be destroyed, with disastrous results to the fly community.

By avoiding longer exposure of the breeding-sites than is necessary to kill *G. morsitans*, one could manage to spare some of the parasites present with possibly beneficial results.

Conclusions.

Log traps are of undoubted value in that they yield a readily obtainable supply of *G. morsitans* puparia for laboratory purposes.

Their economic value cannot yet be estimated, but owing to the low cost at which they can be produced, they are considered to afford distinct practical possibilities for greatly reducing fly density, and possibly exterminating tsetse in small areas.

VI. GENERAL SUMMARY AND CONCLUSIONS.

A small belt of *Glossina morsitans* has been studied for four and a half consecutive years.

The community has been observed during the period of its prosperity when the population increased and attempted to colonise unsuitable country; the outward spread of the fly was checked by insuperable natural barriers, and a period intervened when the fly advance had come to a standstill; the tsetse were observed in their attempt to breed and establish themselves in an area that could only temporarily suffice their needs.

This optimum period was brought to a sudden close by the advent of unfavourable climatic conditions. The effort made by the community to establish a habitat in an unsuitable type of bush was frustrated by the almost complete extermination of its population. The country which had been colonised by the tsetse was depopulated, and once more was limited to a small population that had survived in the true and permanent habitats. A long period followed in which the tsetse were seen to make a slow but steady recovery. The investigation closes with recovery assured, but the community still too depleted in numbers to attempt further expansion for a considerable time.

Throughout this rise and fall in the fortunes of the fly community, the size of the tsetse population has been seen to fluctuate seasonally with the annual variations in the climate.

Time after time in this investigation it has been shown that the key to the proper understanding of the ecology of the fly community lies in the factors that influence climate. Vegetation is considered to be a secondary factor, yet vital in its importance, because the tsetse's ability to withstand the climate depends upon the presence of a favourable vegetation community. Man's greatest ally in his attempt to exterminate the tsetse is the adverse effect of climatic conditions. Man cannot alter the climate, but he can attempt to alter the vegetation type that enables the fly to withstand it.

The writer believes that further research will show that the key to every local fly problem will only be found by discovering the true habitat; investigators will constantly be misled by the discovery of temporary habitats, which can only be utilised by fly in favourable years. After adverse climatic conditions the survivors

of the fly community will congregate within the true home, which can thus be determined. Places where tsetse breed all the year round, where they concentrate after the fires, and where game is always sufficient, are likely to form the true habitats.

The removal of this most favourable vegetation community may have no immediate effect upon the fly, but a year will come when abnormally severe climatic conditions will make it essential for the tsetse to retreat to its true habitat; if this has been removed the fly population will probably be exterminated.

The game factor is not of much importance in limiting the distribution of *G. morsitans* in Tanganyika Territory; there can be few parts where there is not enough game to satisfy the needs of the fly. It is the vegetation that limits the tsetse's distribution, as well as its activities.

It has been shown that there are vegetation communities unsuited to the fly as habitats, but which are used as feeding grounds by those individuals that have failed to find food within the attractive wooding of the home. The method employed by tsetse when hunting for food has been investigated, and it has been found that they follow paths and tend to congregate for a short time at their junction.

G. morsitans is usually inactive at night, and only renews its activities in the morning when the weather has reached a certain degree of warmth and atmospheric dryness.

An attempt has been made to show that the habitats of *G. morsitans* are not essentially different from those of three other species of *Glossina*. Certain vegetation types have been suggested as forming the true habitats of these other species, and it has been shown that their method of hunting for food is very similar to that employed by *G. morsitans*.

After an investigation into the parasites of the district *Syntomosphyrum glossinae* was chosen for the subject of a mass attack upon the fly within its home. A satisfactory technique was evolved for the breeding and liberation of this insect. The experiment in biological control by means of a continuous introduction of large numbers of parasites into the tsetse's breeding sites has not yet been concluded; it would appear that the attempt to clear the area of fly will fail, owing to the parasite's inability to attack puparia in sandy soils. Results suggest that *S. glossinae* might be successfully used in those districts where tsetse breed in humus.

It has been found that if the breeding sites of *G. morsitans* are exposed to the heat of the sun the puparia will be killed. Log traps have been devised which are very attractive to the females of *G. morsitans*; they will desert rock sites in their favour. These traps have been constructed so that the puparia deposited beneath them can be readily destroyed by exposure to the mid-day sun. This method of attacking the fly community through its puparia has not yet been given a large scale trial in the field, but it is considered to hold distinct possibilities. The traps concentrate the breeding of the neighbourhood to a few artificial sites, and are thus at least useful in providing a constant supply of puparia for laboratory purposes.

Some of the results given have already been described or suggested by other workers; however, the value of this paper is believed to lie in the fact that this investigation has been of a continuous nature, uninterrupted by leave movements and other causes. In consequence many of the results have been obtained from large numbers of fly collected over a long period; hence the conclusions reached, whether of an original or confirmatory nature, may have a special value.

The writer is indebted to Mr. C. F. M. Swynnerton, Director of this Department, for his help, which has made a continuous investigation possible; he is also indebted to Captain V. A. C. Findlay, his assistant, who has relieved him of the routine work

of the station during the last three and a-half years. Acknowledgments are also due to Sir Guy Marshall, Director of the Imperial Institute of Entomology, for his kindness in identifying most of the insects mentioned.

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THE INFLUENCE OF TEMPERATURE AND HUMIDITY ON THE PUPATION OF *XENOPSYLLA CHEOPIS*.

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Bacot (1914) records details of breeding experiments with several species of fleas, including *Xenopsylla cheopis*. He bred fleas at a great number of fluctuating temperatures and humidities, and his results show that *X. cheopis* can develop over a wide range of temperature, though not below 16°C.; also, that a high humidity is most favourable. I have shown (Mellanby 1932) that the larva of this species is very easily killed by exposure to dry air—24 hours at 23°C. in perfectly dry air is fatal. Adults, on the other hand, can survive the same temperature for an exposure of 24 hours at all humidities; 39°C. is fatal, while 37°C. is not. But the adults live longer at high humidities than at low (Leeson 1932 *b*). This paper is an account of investigations of the effects of temperature and humidity on *X. cheopis* during its metamorphosis, when it is turning from the non-resistant larva to the resistant adult.

Life-history and Technique.

The larva of *Xenopsylla cheopis* feeds among the debris in the nest of the rodent which is the adult's host. When fully grown, the larva ceases feeding and makes a cocoon of silk and debris. At first the larva remains active, and a sudden increase of temperature or other stimulus will cause it to leave the cocoon. Under favourable conditions, the larva ceases moving and becomes folded double in the cocoon—this stage is the pre-pupa. Then the pupa is formed, from which, after a further period, the adult flea emerges. *X. cheopis* does not usually remain for a long period in the cocoon as a resting larva, or as an imago. The length of the various periods depends on the temperature, and the whole process takes from 13 days at 35°C. to nearly a month at 18°C.

If the full-grown larvae are placed in clean tubes, without any debris, they are still able to pupate. As a rule they do not attempt to form a cocoon, though some spin a little silk. After a few days the larvae show the typical folded appearance of the pre-pupa, and later a naked pupa is formed. Adults from these emerge at about the same time as when proper cocoons are made. It was thought that perhaps the larvae in clean tubes made no cocoons because they had not really finished feeding—the larvae in the debris, which made cocoons, had not been removed from their food, and might have continued feeding before spinning the silk. But cocoons were always formed by larvae placed in clean silver sand freed from organic matter, so the stimulus to spin is probably mechanical.

The fleas were bred by the method described by Leeson (1932 *a*), and larvae removed from the culture by the method he recommends. The work was done in the Entomological Department of the London School of Hygiene and Tropical Medicine. The strain of *X. cheopis* was derived from specimens sent from Ceylon by Dr. L. F. Hirst.

To find what Humidity limits Development.

The flea larvae were placed in 2 in. by 1½ in. glass tubes, in batches of 20, with a little debris containing sand, flea faeces, etc. The tubes were sealed with pieces of muslin, to prevent emerging fleas from escaping. The tubes were stood in desiccators, which were kept in incubators at the various temperatures. The humidity of the air inside the desiccators was controlled by mixtures of sulphuric acid and water (see Buxton 1931).

The larvae were exposed to four temperatures—18°C., 22°C., 29°C. and 35°C.—and to several humidities at each temperature. Fig. 1 shows the results obtained. At the three lower temperatures, the fleas developed satisfactorily at 60 per cent. or higher relative humidities; at 40 per cent. or below they died very soon. At 35°C., 70 per cent. relative humidity was found to be too dry to allow development. Some larvae were also exposed to 14°C. and 8°C., temperatures too low to permit development, and lived for weeks in moist air, but they died in a few days in dry. In the preliminary experiments, one batch of 20 larvae was used at each combination

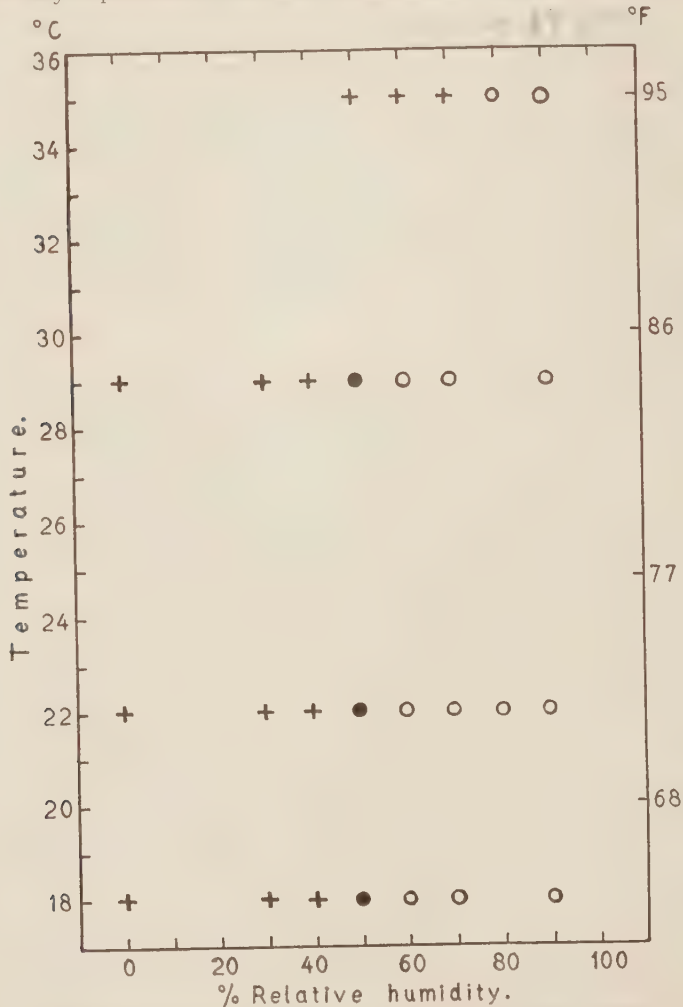


Fig. 1. Conditions under which *Xenopsylla cheopis* larvae pupated. A cross indicates conditions where no adults were produced. A black circle means that under 75% of the larvae gave adults, and a white circle that over 75% did so.

of temperature and humidity. Most of the experiments were repeated, and over 100 larvae were used at those points at which uncertain results were obtained. Over 3,000 larvae in all were used. Under those conditions marked on fig. 1 with a circle, over 75 per cent. of the larvae produced adults. As it was not possible to be sure that all the larvae were full-grown, I do not think that the difference between a 75 and a 100 per cent. emergence is significant.

At what Stage does the Flea cease to be susceptible to Dryness?

Larvae were allowed to spin cocoons in debris, at 22°C. and 90 per cent. relative humidity. Within 24 hours the cocoons were removed to another desiccator at the same temperature, but containing air with a relative humidity of 30 per cent. No fleas emerged, and when these cocoons were opened a month later they were found to contain dried up larvae. If, however, the cocoons were kept for 8 days in moist air at 22°C. before transferring to the dry, fleas emerged in due course. (By this time pupation had occurred—see Table I.)

Other larvae were placed in clean tubes at 22°C. and 90 per cent. relative humidity. In a short time the folded prepupal stage was observed and transferred to the dry air; the larvae dried up, and never pupated. But when naked pupae were transferred to a lower humidity, they developed satisfactorily. They were even able to withstand a relative humidity of 0 per cent. at 30°C., under which conditions larvae lived only a few hours.

It was noticed at 35°C., in air of 70 per cent. relative humidity, that the larvae made cocoons but that no fleas emerged from them—the larvae drying up before pupation could take place. This was frequently observed to happen at the lower temperatures, at 50 per cent. relative humidity.

The experiments described above indicate that the pupa, like the adult, is resistant to dry air. The larva and prepupa are not resistant, and the cocoon is no protection against the dryness.

The Time taken by the Larva to pupate at different Temperatures.

To find what period the larvae took to pupate, it was necessary to open a large number of cocoons of known age, as it is not often possible to see inside. The cocoons were formed at each temperature in desiccators with air with a relative humidity of 90 per cent., but I also examined a number of cocoons formed at lower humidities, and the pupa appeared to be formed in the same time.

TABLE I.
Time taken by Xenopsylla cheopis Larvae to pupate.

Temperature °C.	Stage	Days									
		1	2	3	4	5	6	7	8	9	10
18	Pupae					0	0	10	47	26	
	Larvae					12	15	39	7	0	
	% pupae					0	0	20	87	100	
22	Pupae				0	5	37	43			
	Larvae				16	31	10	0			
	% pupae				0	14	79	100			
29	Pupae		0	10	52	9	7				
	Larvae		11	44	12	0	0				
	% pupae		0	18	81	100	100				
35	Pupae		0	7	28						
	Larvae		30	26	0						
	% pupae		0	21	100						

Total—534 cocoons opened.

The results obtained by opening cocoons are shown in Table I. Each number is the total of several small batches opened on each day. It will be seen that the

pupa is formed much more rapidly at the higher temperatures. The days are numbered from the time the cocoon was made (Day 1) until the day on which it was opened. Larvae were kept at $14^{\circ}\text{C}.$, under which conditions no pupae were formed. In one experiment the temperature was allowed to rise to $16^{\circ}\text{C}.$ after being kept for a week at $14^{\circ}\text{C}.$; the larvae made cocoons and pupated, and adult fleas emerged after about 6 weeks. Thus, for pupation, the developmental zero appears to be about $15^{\circ}\text{C}.$ It is possible to express these figures graphically, as in fig. 2. It will be seen that the points representing the times of pupation fall on a curve which, continued downwards, indicates that pupation would take an almost infinite time at $15^{\circ}\text{C}.$ Although 534 cocoons were opened, there are not sufficient data for statistical treatment by means of which the points in fig. 2 could have been more accurately determined. To obtain a really accurate curve, it would be necessary to open many more cocoons at more frequent intervals.

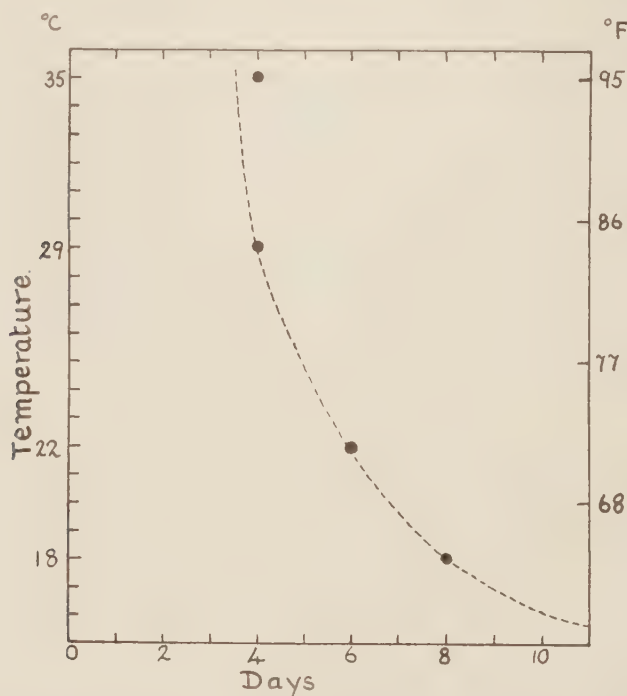


Fig. 2. Time taken by fully fed *Xenopsylla cheopis* larvae to pupate.

As we considered that when 75 per cent. or more of the larvae produced adults the conditions were satisfactory, I shall also take the time which 75 per cent. of the larvae took to pupate as a measure of the time required for pupation. The periods, then, were as follows:—

At $14^{\circ}\text{C}.$ —No pupae formed					
„	$18^{\circ}\text{C}.$ —	More than 75 per cent.	pupated in	8	days
„	$22^{\circ}\text{C}.$ —	„	„	„	6 „
„	$29^{\circ}\text{C}.$ —	„	„	„	4 „
„	$35^{\circ}\text{C}.$ —	„	„	„	4 „

Discussion.

The experiments described show that *Xenopsylla cheopis* can complete its life-history between 18°C. and 35°C., in moist air. Between 18°C. and 29°C., air with a relative humidity of 40 per cent. is unfavourable, while with 60 per cent. pupation takes place successfully.

Now the rate of loss of water from an insect is believed to be generally proportional to the saturation deficiency of the air. If this is the case, then it cannot be proportional to the relative humidity. If this holds good for *X. cheopis*, the lowest humidity at which development can take place should have approximately the same saturation deficiency at each temperature. An examination of fig. 1 at first seems to show that this is not the case—the lowest humidity compatible with satisfactory development is 60 per cent. at 18°C., 22°C. or 29°C., when the saturation deficiency is 6.2, 8.0 and 12 mm. respectively.

But there is one point of difference between *X. cheopis* and many other insects. Here we are dealing with a larva which dries up easily, but which turns into a resistant pupa. The pupa is formed after a different period at each temperature, and this means that the susceptible stage lasts for a different time at each temperature. Now if the flea larva loses water at a rate proportional to the saturation deficiency of the air—and it can only lose a certain amount of water and survive—it will be able to withstand a greater saturation deficiency at a higher temperature than a low, because it will be losing water for a shorter time. Also, if the rate of loss is strictly proportional to the saturation deficiency, then the product of the time required to pupate and the saturation deficiency of the lowest humidity which allows pupation at each temperature should be constant. This factor is worked out in Table II, and it will be seen to be almost constant for 18°C., 22°C. and 29°C. The result at 35°C. is lower, but this is probably because the insects are at a temperature above their normal range and are more active than usual.

TABLE II.

Temperature °C.	Days to pupate	Lowest relative humidity for satisfactory development	Saturation deficiency	Saturation deficiency × days to pupate
18	8	60	6.2	49.6
22	6	60	8.0	48.0
29	4	60	12.0	48.0
35	4	75	10.5	42.0

Summary.

1. The conditions of temperature and humidity under which *Xenopsylla cheopis* is able to complete its metamorphosis are described.
2. The larvae and pre-pupae are easily killed by drying, but the pupae are not. The cocoon does not protect the larva from drying.
3. Development is much quicker at high than at low temperatures.
4. The rate of loss of water from the larva appears to be proportional to the saturation deficiency of the air, at any rate at 18°C., 22°C. and 29°C.—when the time which elapses between spinning the cocoon and the formation of the pupa is taken into account.

The writer is indebted to Dr. P. A. Buxton for reading and criticising the manuscript.

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METHODS OF AUTOMATIC COLLECTING FOR STUDYING THE FAUNA OF THE SOIL.

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When studying the fauna of the soil it is obviously of the utmost importance to use such methods of collecting the animals as are thoroughly reliable and efficient, so that one can be reasonably sure of getting practically all the animals existing in a given material. It is not to be expected that one method will ensure successful collection of all the animals, because some react in one way towards the agents chiefly used, *viz.*, strong light and heat, others react in another way. For instance, some animals, such as Tardigrades and Rhizopoda, encyst themselves when subjected to dryness and cannot be forced to move downwards away from the light and dryness as most arthropods do. As pointed out by the author (1928) all methods of mechanically separating the animals from the substratum by sieves, etc., are worthless unless applied to larger animals such as Oligochaeta, larger beetles and snails. For all smaller animals the only safe method is the automatic one based on their reactions towards light and dryness, which was devised by the late Professor A. Berlese in Florence in 1905.

This apparatus is so well known that it is not necessary to give a detailed description of it, nor need I dwell on the more or less similar apparatus constructed later, except Tullgren's, because the latter, constructed in 1917, has been used by several investigators. Tullgren substituted the funnel filled with water and heated by gas, which Berlese used for the purpose of drying the material containing the micro-arthropods to be collected, by an electric bulb suspended above the material in a cylindrical funnel at a distance of about 5 cm. above the material. Tullgren asserts that in this way he succeeded in collecting during 2-3 hours all the animals from the material thus treated.

It is, however, evident that neither Berlese nor Tullgren made any experiments in order to ascertain the efficiency of their methods, which is explained by the fact that neither intended to use them for other purposes than the mere collecting of micro-arthropods that interested them, and did not imagine that they would be employed for detailed statistical investigations of different biocoenoses.

Nevertheless several investigators, such as v. Pfitzen, Pillai and Bornebusch, have adopted Tullgren's method without troubling to ascertain by special experiments whether it was efficient or not.

During the investigations of the fauna of the soil in Swedish forests carried out during recent years at the Royal Swedish Institute of Experimental Forestry, a method has been devised which conforms with Berlese's in so far that the sample of moss, pine needles, dry leaves, etc., to be investigated is desiccated through the action of a layer of water surrounding the funnel which supports the sieve on which the material is spread out, the water being heated by a petroleum lamp. But whenever the temperature in the laboratory and the climate permitted it, the material was allowed to dry more slowly. This entailed a longer period of treatment, it is true, but on the other hand, it was considered that this method reproduced more closely the conditions obtaining in the forest during periods of drought.

Nevertheless I did not abandon the idea of finding a method which combined sufficient expediency with as great a measure of reliability as possible.

For this reason a series of experiments were carried out last year in order to compare the advantages and disadvantages inherent in Berlese's and Tullgren's methods. Such a comparison was, moreover, an urgent necessity on account of the very remarkable results obtained by Bornebusch in Danish forests, results which differed to such an extent from those obtained by me in forests of the same type in the south of Sweden that the discrepancy could not be explained as being due to a real variation in the composition of the fauna of the soil in these forests, but must be attributed to defects in the method employed.

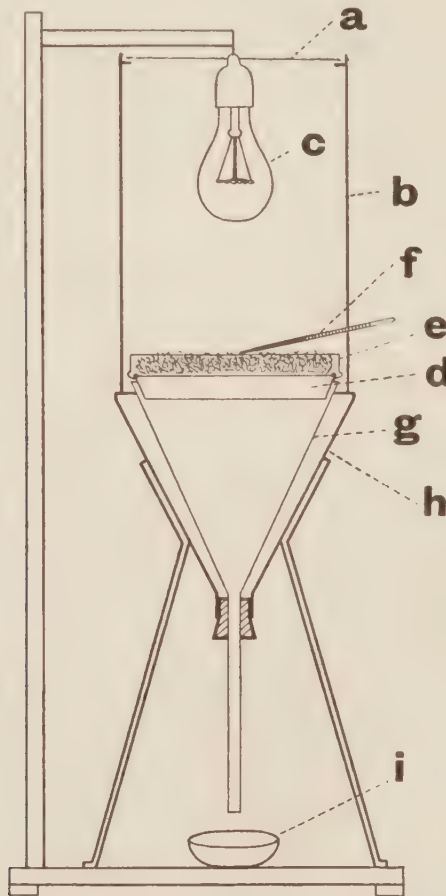


Fig. 1. Apparatus for automatic collecting of the fauna of the soil by illuminating it from above with an electric lamp: *a*, circular disk of cardboard with marginal incisions for the escape of the humidity; *b*, funnel of tin-plate; *c*, electrical bulb; *d*, metal ring holding a sieve; *e*, the material to be treated; *f*, thermometer; *g*, glass funnel surrounded by a copper funnel (*h*); *i*, collecting cup.

Thus Bornebusch gives 20,650 as the maximum number of Acarina to a square metre in a spruce forest in Sjaelland. The corresponding number from a spruce forest at Dalby in the south of Sweden is 275,800. Of 17 samples from Dalby 5 had more than 200,000 specimens in a square metre, 9 samples had more than 100,000 specimens, and only 3 had less than 100,000, with a mean number of 64,200.

As regards the Collembola the discrepancy between Bornebusch's and my own data is still greater. That author records a maximum number of 4,830 Collembola to a square metre, while my corresponding number is 282,500, and the mean of 17 samples is 120,000 specimens. It does not seem possible to believe that this extraordinary difference gives a true picture of the population of Collembola in a spruce forest in Sjaelland and in Scania.

It seems to be of special significance in this connection that Bornebusch only records 3 fairly large species of the great group Trombidiformes, which is so abundant in small, soft-bodied and exceedingly common species, such as *Tydeus* and *Eupodes*. And the assumption does not seem unfounded that, as I pointed out in 1928 (*l. c.* p. 796), too strong heating of the material may have such a deleterious influence on the smallest species, which generally have the softest cuticle, that they succumb before they have had time to crawl down into the funnel. Another fact, which undoubtedly has greatly contributed to make Bornebusch's catches so small, is that he has not used a magnification strong enough to enable him to observe the smallest micro-arthropods, nor the proper background to discern them. In order to test the efficiency of the lenses ($8\times$) and the background (a shallow cup of white porcelain) which he used, I poured out the contents of a small glass tube containing 100 previously counted micro-acarina (*Tydeus* and small nymphae of Oribatids) and examined them under a binocular microscope magnifying 10 times; I was just able to see one of these mites, a *Rhagidia* larger than the others, the rest being invisible. By using $30\times$ magnification and a dark blue background I was able to recover 94 of the 100 specimens. This shows how easily the smallest forms may be overlooked even when special precautions are taken. How many per cent. escape when insufficient magnification and an unsuitable background are used, one may guess from the foregoing experiment.

But this loss is not enough to explain the enormous discrepancy between Bornebusch's and my own data. As pointed out above one must assume that the method of drying the material by using an electric lamp suspended above is deleterious at least to the smallest of the micro-arthropods.

In order to test the validity of this assumption and for the purpose of securing a more detailed knowledge of the temperatures obtained, of the progress of the drying of the material, and its action on the catching of the animals, a series of experiments was carried out. The apparatus used is delineated in fig. 1. Two lamps of different strengths were used, *viz.*, 40-watt (I), giving a temperature of 40–50° Celsius, and 25-watt (II) giving a temperature of 30–40° Celsius; and for comparison the temperature of the laboratory (17–20° Celsius) was used. On the three sieves the same quantity of a material as uniform as it was possible to find was spread out, and the temperature was registered, the material weighed and the collecting-cups changed every hour.

Fig. 2 gives the result of the first experiment. The animals were for this purpose divided into five groups and the thick-skinned Acarina, embracing the full-grown Oribatids and all the Gamasids, were separated from the thin-skinned Acarina, embracing Trombidiformes such as *Tydeus*, *Eupodes*, etc., and the nymphae and larvae of Oribatids. The numbers refer to 100 grams of material dried at 100° Celsius.

From the experiment it is at once evident that Tullgren's method is totally unsuitable for the collection of earthworms. Although the numbers present in the material are rather small, it is noteworthy that 22 specimens were collected in the material left to dry at room temperature, but only 2 in apparatus I. As regards the thick-skinned Acarina, the Collembola and other arthropods the differences are too small to take into consideration. But in the case of the thin-skinned Acarina

the deficit in apparatus I is very great, amounting to nearly 50 per cent. of the number obtained when the material is left to dry slowly, or in absolute numbers 38,900 specimens in 1,000 grams of dry substance.

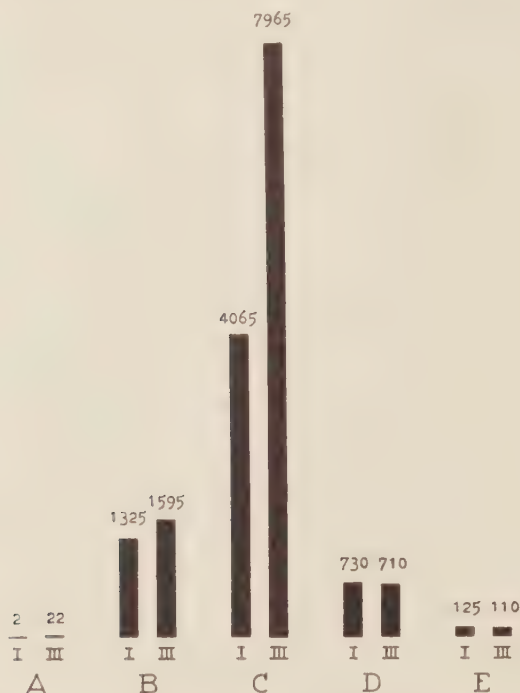


Fig. 2. Graphical illustration of the results of automatic collecting by the apparatus in fig. 1. The material was either dried by being illuminated from above by a suspended 40-watt lamp (I) or at room temperature (III). The material consisted of spruce-needles and litter from an old spruce forest in the vicinity of the Institution, collected in July 1931. Original weight 90 gr., dry weight 50.4 gr. Percentage organic matter 82.5. A, earth-worms; B, thick-skinned Acarina; C, thin-skinned Acarina; D, Collembola; E, other arthropods. The figures refer to 100 grams of dry material.

It is obviously not a mere coincidence that just these two groups, the earthworms and the thin-skinned Acarina, show the greatest deficit when the material is treated with Tullgren's method, because earthworms, owing to their thin cuticle, are notably highly susceptible to drought; and the same applies to the smaller Acarina, which moreover, partly owing to their minute size, are very sluggish in their movements and therefore succumb in great numbers to the heat and strong light before they have had time to escape into the deeper layers of the material. The very vivacious Collembola, on the other hand, escape rapidly and do not suffer from the heat or the strong light, and the larger Oribatids and Gamasids are adequately protected by their thicker cuticle.

The time required for collecting the animals was 22 hours in apparatus I, during which time the weight decreased from 90 to 50.4 grams. The corresponding time with apparatus III was 8 days.

In the next experiment material from the same locality as in the first experiment was used, but it was collected later in the autumn, in November. The results obtained

by the use of a 40-watt lamp (I), a 25-watt lamp (II) and room temperature (III) are seen in fig. 3. They agree closely with those obtained previously, with the exception that the Collembola are far less numerous, owing probably to the fact that in

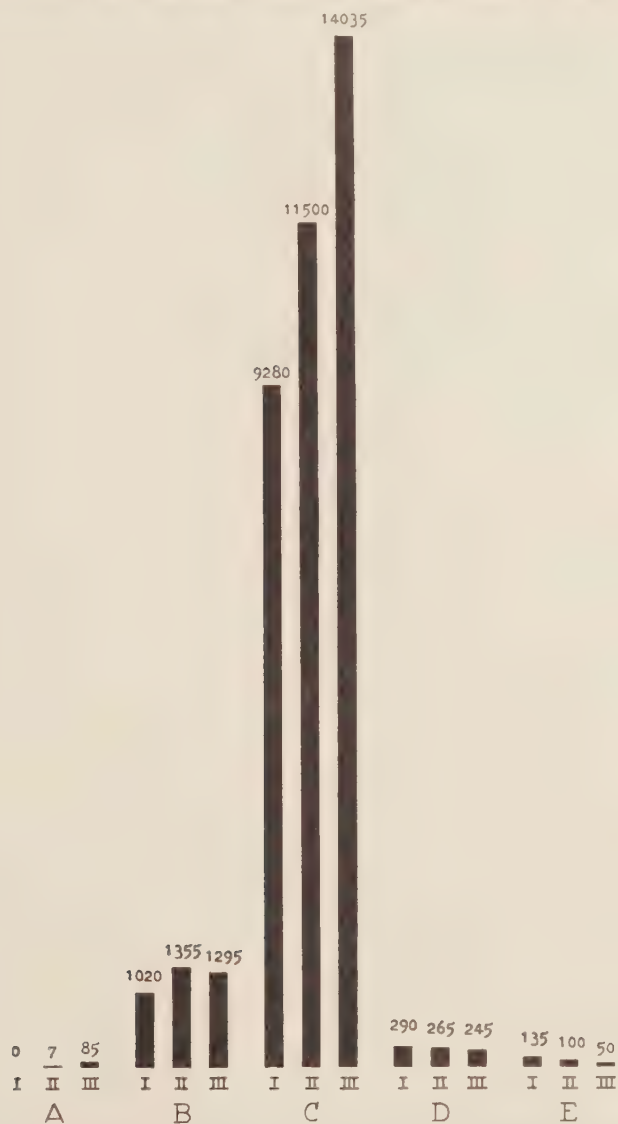


Fig. 3. Graphical illustration of the results of automatic collecting by the apparatus in fig. 1. Material dried as in previous experiment by 40-watt lamp (I) or 25-watt lamp (II) or at room-temperature (III). The material is spruce-needles and litter from the same locality as in the previous experiment but collected in November 1931. Original weight 90 gr., dry weight 28.4 gr. Percentage organic matter 82.5. For explanation of letters *vide* fig. 2.

November many of them are in the egg stage, in which it is impossible to collect them in this manner. The same applies probably, although in a smaller degree, to the thick-skinned Acarina; the thin-skinned Acarina, on the other hand, are far more

numerous during this season. The deficit of the thin-skinned Acarina in method I is 4,755 per 100 grams, or 47,550 per 1,000 grams, as compared with method III, and method II is better than I but shows, nevertheless, a deficit of about half that of method I.

As regards the earth-worms the result coincides closely with that of the former experiment, even the 25-watt lamp proving to have a destructive influence on these animals. This is a sufficient proof that Tullgren's method, even when less strong light is employed, is quite useless for collecting earthworms. The reduction in the catch of the thin-skinned Acarina also is so great when dry needles, spruce-litter and humus are treated, amounting to 33-49 per cent. with the stronger lamp, that this method must be discarded; the action of the 25-watt lamp is less deleterious, giving a deficit of only about 17 per cent., but even this is too great.

During the experiments the temperature was observed every hour, and the material was weighed and the catch investigated also every hour. The result of these investigations are illustrated in figs. 4-6. The total amount of humidity evaporated during the course of the treatment and after drying the remaining material at a temperature of 100°C. was taken as 100, and the different data obtained were calculated in percentages of this amount.

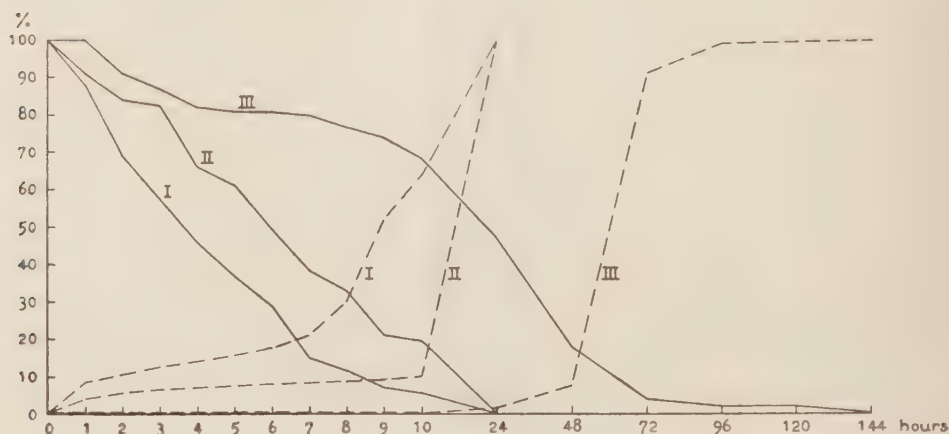


Fig. 4. Diagram illustrating the course of the desiccation and the collecting of sample fig. 3. — = percentage of humidity; - - - - - = percentage of catch every hour. I = 40-watt lamp (40-60°C.), II = 25-watt lamp (36-46°C.), III = room temperature (20-22°C.).

A corresponding method of calculating the percentage of the entire catch collected every hour was used.

Amongst the most conspicuous features of these charts are the following:—

1. That in all the three experiments the point of desiccation exerting the most active influence on the downward migration of the arthropods was nearly identical, *viz.*, about 20 per cent. Until this threshold of deficient humidity was reached, after 6.30 hours in I, 10 hours in II, and 48 hours in III, very few animals crawled down into the funnel. But once the humidity sank below this degree the emigration became exceedingly rapid. It seems safe to assume that this wholesale emigration is brought about by the gradual desiccation of the upper layers of the material causing the animals to congregate in the lower, more humid layers. But when finally even these layers acquire a degree of humidity below the critical 20 per cent., then the real downward emigration is completed in a comparatively short time.

2. From the diagram (fig. 4) it is evident that during the first hour of treatment the emigration is far more pronounced than during the following hours, when illumination from above is used, *viz.*, 8.8% in I and 4.3% in II, which amount in I is not reached again until after 8 hours and in II after more than 10 hours. This rapid reaction obviously cannot be related to the desiccating influence of the lamps, but is rather due to the negative phototropism of many of the micro-arthropods. This view is strengthened when studying in detail what animals wander downwards during the first hour. These comprise all the diplopods, about 50 per cent. of the Collembola, and 100 per cent. of the beetles and of the larvae of Microlepidoptera. All these have eyes and are presumably negatively phototropic, whereas most of the Acarina are blind, and although they have sensorial organs, such as the pseudostigmatic organs of the Oribatids, it is evident that they either react more slowly towards the light or their far smaller size, as compared with the insects, renders their locomotion slower, or else both these conditions combine to retard their emigration.

It is, however, evident that the reaction of the animals towards the lamp is two-fold: a rapid, more direct reaction of the negatively phototropic insects and myriapods towards the light, and the negative reaction of the Acarina against the decrease in humidity below a certain degree.

The more the population of the soil is composed of insects and myriapods the more rapid and effective is the action of the lamp, and I suppose that the statement of Tullgren, quoted above, as to the astonishingly short time necessary to catch all the animals, in reality only refers to these forms.

The experiments just described show, however, that a period of 10 hours is too short a time to enable us to follow in detail the wandering downwards of the population of the soil. Hence it was necessary to make new experiments covering at least 24 hours. This time a moss (*Leucobryum longifolium*) was used that was growing on the cliffs close to the institution. It was anticipated that the population of this biotope would display a different reaction from that used in the former experiments, because it is obvious that the population of the soil in a fairly dense spruce forest is ordinarily not exposed to any extreme and rapid changes in the humidity or temperature of the soil, and is, moreover, able to obviate any detrimental conditions by penetrating into deeper layers of the soil.

The inhabitants of a moss-tuft growing on a cliff, on the other hand, are obviously subjected to very pronounced changes both positive and negative in these respects, because during periods of drought and insolation the moss becomes as dry as tinder, and during heavy rains it absorbs as much water as a submerged sponge; and in neither case are the animals able to evacuate their abode or to wander far downwards, but must perforce remain where they are, seeking what protection they may contrive to find within the limited space of the moss.

The ability of withstanding even great variations in the humidity must therefore *a priori* be a characteristic feature of the inhabitants of this biotope.

Fig. 5 illustrates the results obtained during these experiments. When comparing them with those previously obtained it is necessary to point out that in apparatus I the temperature did not rise so high as previously, varying between 39.6 and 49°C. and only very rarely exceeding 50°C.

We notice the following features:—

1. That in spite of the lower temperature the moss dried quicker than the needles + spruce-litter.
2. That no marked downward emigration took place during the first hour. This is explained partly by the very rare occurrence of insects, partly by the assumption that the population of this biotope is necessarily too much used to strong light to react towards it in the same way as those of the previous biotope.

3. The population proved to be far more resistant towards the lowering of the humidity than in the previous experiments. In apparatus I the emigration increased from 1 to 4 per cent. when 8 to 16 per cent. humidity was reached; a further lowering of the humidity entailed an increase to 8 per cent., the maximum effect 27 per cent. being attained at a further decrease of the humidity to 4.5 per cent. In apparatus II the increasing and the decreasing of the downward emigration is much slower, the maximum 11 per cent. being reached during the 11th hour, coinciding with 7.5 per cent. of humidity. A very remarkable feature is that even the complete desiccation of the material after 14 hours did not result in the capture of more than 39 per cent. of the population, which shows how very resistant the animals of this biotope are to drought.

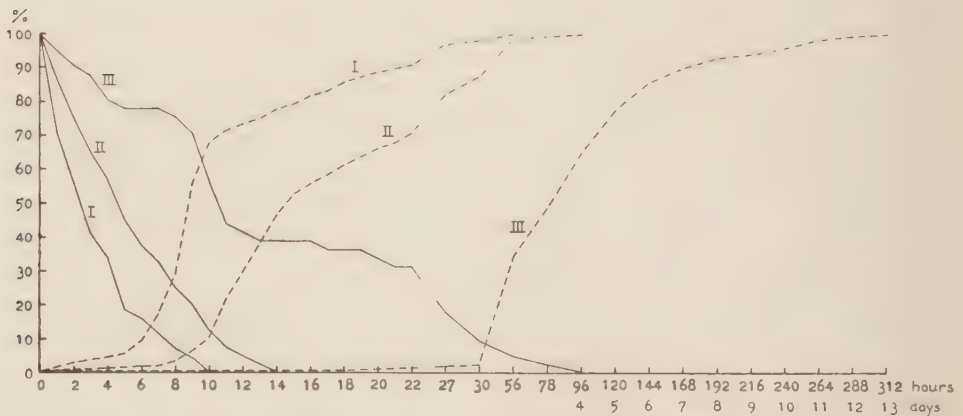


Fig. 5. Graphical illustration of the results of automatic collecting by the apparatus in fig. 1: I = 40-watt lamp; II = 25-watt lamp; III = room temperature. The material consisted of moss (*Leucobryum longifolium*) growing on a cliff in the vicinity of the Institution. The sample was collected in January 1932. Original weight 55 gr., dry weight I = 10.3 gr., II = 14 gr., III = 13.1 gr. Percentage organic matter 83.2. The figures refer to 10 gr. dry moss.

In apparatus III the critical degree of lowering the humidity, about 10 per cent., was not reached until after 30 hours, 80 per cent. of the population emigrating during the following 114 hours. Even during one entire week after complete desiccation, animals continued to emigrate, a feature so remarkable that one is almost inclined to assume that many of these animals during the beginning of the experiments were in the egg-stage and hatched owing to their being subjected to a higher temperature.

4. A comparison between this experiment and the previous one elicits the two fundamental facts that the critical degree of humidity is approximately the same in the same biotope regardless of the treatment, but differs greatly in different biotopes.

Fig. 6 gives the result of this experiment so far as the total collection of animals is concerned, the figures in this instance referring only to 10 grams. We notice at once how exceedingly abundant the population of the moss is in comparison with that of the spruce-needle and litter layer, viz., in apparatus I a total of 451,300 per kilogram against 107,250, in apparatus II a total of 130,500 against 132,200, and in apparatus III a total of 262,000 against 156,250. Further we notice that the results obtained in this experiment are strikingly different from the previous ones.

Slow drying at room temperature, which gave the best result with spruce litter, in this instance gave a deficit of nearly 35 per cent. for the thin-skinned Acarina and 60 per cent. for the Collembola. When trying to form an opinion on the causes underlying the different action of the same methods on the inhabitants of the two biotopes,

it seems safe to assume that the deficit in apparatus III in sample no. 161 cannot possibly be due to desiccation, since this factor was more pronounced in I and II without any detrimental results. It seems more easily explained as being due to the absence of illumination from above. As previously pointed out the population of this biotope is obviously used to far stronger light than is that of the former biotope, from which we may infer that it takes stronger light than in the former experiments to cause their negatively phototropic reaction, which is manifested in the downward emigration. In the absence of this guiding influence of the strong light — because the light in the room close to the inner wall was not strong enough to offer any guidance — it is very likely that many animals disappeared over the edge of the sieve, while others wandered about aimlessly in the moss until they succumbed to the dryness. Whatever is the cause of this difference in the catch, it is a fact to be reckoned with.

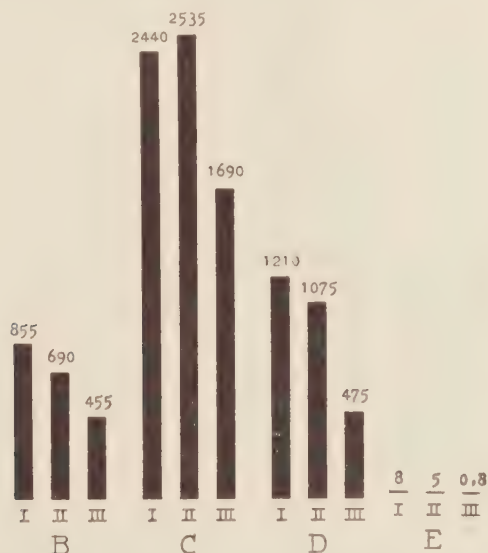


Fig. 6. Diagram illustrating the course of the desiccation and the collecting of the sample in fig. 5. For explanation of letters *vide* fig. 2.

The conclusion is that when collecting by automatic methods the animals of such biotopes as *Leucobryum longifolium* Tullgren's method with a 40-watt lamp is the best.

In order to gather more experience regarding these methods of collecting in different biotopes I next used a peat-moss (*Sphagnum girgensohni*) containing 96 per cent. of water. It may be fairly assumed that the population of this biotope is subjected to less variations in the humidity than in any of those previously investigated owing to the great capacity of *Sphagnum* to absorb and retain water.

The composition of the fauna is illustrated in fig. 7, which gives the result of the experiments, and fig. 8 illustrates the course of these. The scarcity of the Collembola is a very striking feature of this biotope, and the absence of a marked downward migration is obviously explained by this and by the small number of other arthropods.

In this instance the 25-watt lamp gave the best result, the stronger lamp giving a deficit of 47 per cent. of the thin-skinned Acarina. The discrepancy between the results of the strong lamp and the room temperature on the catch of the thick-skinned and the thin-skinned Acarina is at present impossible to explain, but both give deficits big enough to make these methods useless.

As a general remark, stress may be laid upon the fact that in all three experiments the humidity decreased very slowly. In view of the close proximity of the humidity curves of I and II it is astonishing to find such a great interval as more than 5 hours between the two maximum downward migrations.

Possibly the structure of the *Sphagnum* puts obstacles in the way of the small Acarina, which moreover are very slow in their movements.

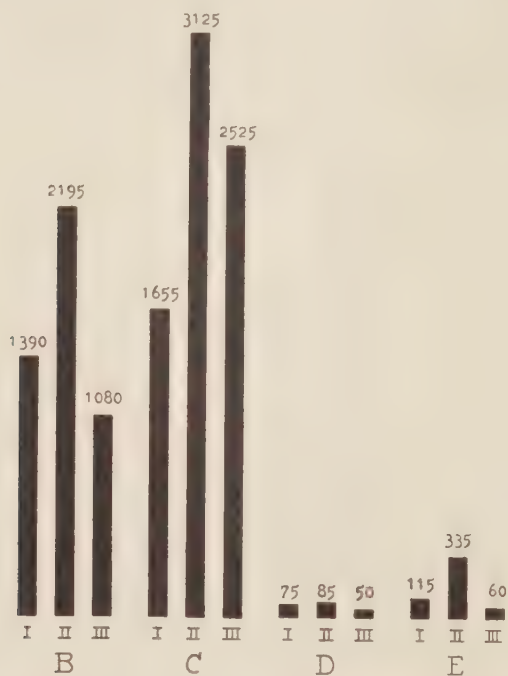


Fig. 7. Graphical illustration of the results of automatic collecting by the apparatus in fig. 1: I = 40-watt lamp; II = 25-watt lamp; III = room temperature. Letters as in fig. 2. The sample (no. 157) consisted of peat-moss (*Sphagnum girgensohnii*) mixed with a little *Polytrichum commune* growing in small depressions in mixed spruce and pine forest on a moraine, collected 26th November 1931, at Lotorp 7 km. from Fiskeby. Original weight 55 gr., dry weight 2.5 gr. Percentage organic matter 97.1. The figures refer to 10 gr. dry moss.

Very striking is the extraordinary power of these tiny creatures of withstanding the most adverse conditions. In apparatus III where, in the course of 3 days, the weight decreased from 55 to 2.5 grams, one would expect that those mites which had by this time not made good their escape would succumb. Far from it, they continued during the following 8 days to crawl down into the cups.

A serious objection may, however, be raised against the three methods here used, *viz.*, the great length of time they require. In order to obviate this, several methods were tried, but the only one that showed promising results was to keep the material to be treated in a tightly closed box of wood-pulp in which chloride of lime (Ca Cl_2) was suspended. In this way it was possible to lower the humidity to about 50 per cent. in two days. And as fig. 8 shows, this resulted in shortening the period of treatment with a 25-watt lamp, which in other circumstances would have required 25 hours (comp. fig. 4), to 6-8 hours.

The previously established fact that a lowering of the humidity to 50 per cent. had no great influence on the emigration of the animals may safely be considered as evidence that this has no injurious effect on them. Hence the treatment with chloride of lime could be considered a safe procedure, and, as a matter of fact, the catch from this material, which was spruce litter from exactly the same locality as used above, was almost identically the same as in the July experiment (comp. fig. 2) for all groups except other arthropods, which difference is explained by the different season.

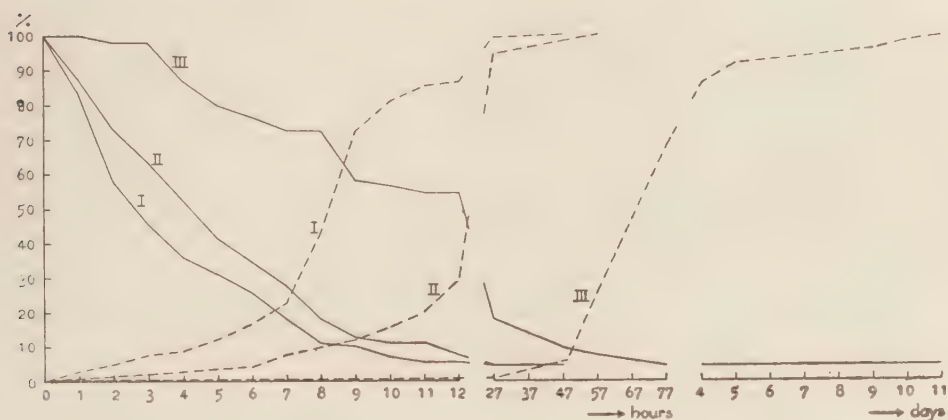


Fig. 8. Diagram illustrating the course of desiccation and the collecting in sample no. 157 (fig. 7). — = percentage of humidity; - - - - = percentage of catch every hour; I = 40-watt lamp (40–50°C.); II = 25-watt lamp (30–40°C.); III = room temperature (17–18°C.).

The results of the foregoing experiments may be formulated thus :—

1. The action of a lamp suspended above the material is twofold : one direct and fairly immediate, resulting in the rapid emigration of those animals that react negatively phototropically towards the light ; and the more slow indirect action of the light and the heat resulting in a lowering of the humidity on which the downward migration ensues, which accelerates rapidly when a threshold of desiccation is reached, which is different in different biotopes.

2. When the majority of the population is composed of larger Collembola and other insects, these may be rapidly (3–4 hours) caught by the use of Tullgren's method.

3. On the other hand, this method is worthless for the purpose of collecting earthworms.

4. Nor does it give satisfactory results when the collecting is done in dark and damp biotopes, especially when the small thin-skinned Acarina are numerous.

5. When collecting in very dry biotopes, as in moss on cliffs, a 25-watt lamp gives the best result, likewise in other mosses where the slow drying method seems to endanger the escape of the thin-skinned Acarina.

6. It is feasible to shorten very considerably the time of automatic collecting by lowering the degree of humidity to about 50 per cent. by keeping the material to be treated for 2–3 days in a close box containing chloride of lime (CaCl_2) suspended.

7. The biocoenoses of different biotopes differ so greatly in composition and reaction towards light and low humidity that it is impossible to draw any conclusions from one sample concerning the treatment of another sample.

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GALL MIDGES (CECIDOMYIDAE) AS ENEMIES OF MITES.

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*Entomology Department, Rothamsted Experimental Station, Harpenden, England.***1. Introduction.**

This is a third of a series of papers dealing with zoophagous gall midges of the world. The first, "Gall Midges as Enemies of Aphids," was published in 1929 (Bull. Ent. Res., xx, 1929, pp. 433-442) and the second, "Gall Midges as Enemies of the Tingidae, Psyllidae, Aleyrodidae, and Coccidae," appeared more recently (*op. cit.*, xxi, 1930, pp. 319-329).

In this paper the species of gall midges whose larvae have been reported as preying on mites are dealt with, the first reference mentioned being in each case that of the original description or record. Practically all the literature available consists of specific descriptions and little is stated about the bionomics of the species with a few exceptions. It is a matter for regret that such scant attention has been paid to this aspect of biological control, especially in view of certain statements claiming that the larvae of various gall midges are of considerable importance in the natural control of red spider. It is with a view to stimulating further research in this direction that the present paper has been compiled.

It has been thought advisable to divide the paper somewhat arbitrarily into separate sections, dealing firstly with those species of gall midges preying on free-living mites and secondly with those species preying on gall-inhabiting mites. A further section deals with those Cecidomyids which may feed on mites. As an additional convenience, a list of plants on which the mites live is appended. The Cecidomyids which may be predacious on mites (see section 5) are not, however, included in this list.

I am indebted to Mr. A. M. Massee, of the East Malling Research Station, for his kind assistance with regard to Mite nomenclature.

2. Addenda to "Gall Midges as Enemies of the Tingidae, Psyllidae, Aleyrodidae and Coccidae."*Clinodiplosis latibulorum* (Winn.).Winnertz, Linn. Ent., Stettin, viii, 1853, pp. 247-248 (*Diplosis*).Kieffer, Genera Insectorum, fasc. 152, 1913, p. 238 (*Clinodiplosis*).

Boselli, Boll. Lab. Zool. Portici, 1928, p. 249.

This species, of which the male and female were described from Germany by Winnertz, is recorded by Boselli as attacking *Physokermes abietis* (Geoff.) in Italy.

Unknown Cecids.

P. E. Keuchenius (Meded. v. L. Besoekisch Proefstation, Djember, no. 16, 1915, p. 63; R.A.E., A, iii, 1915, p. 648) mentions a Cecidomyid as preying on *Pseudococcus bicaudatus*, Keuch., in Java. He states that it may be *Diplosis acarivora*, Zehnt., but the present writer considers this improbable.

J. C. Koningsberger and A. Zimmerman (Meded. u. 'Slands Planteum, xlv, 1901, p. 34, pl. 1, figs. 19, 20) record and figure a Cecidomyid as parasitic on *Pulvinaria psidii* in Java on coffee.

Arthrocnodax apiphila, Felt.

This species was reared once from a twig badly infested by *Pulvinaria vitis*, Linn. For further information see *A. apiphila* in section 3 of this paper.

Schizobremia formosana, Felt.

Barnes, Ann. Mag. Nat. Hist. (10) ix, 1932, p. 478.

This species was originally reared from *Pseudococcus brevipes*, Ckll. More recently it has been reared from *P. filamentosus*, Ckll., in Formosa.

Silvestrina koebelei, Felt.

Felt, Pan-Pacific Entomologist, viii, 1932, pp. 167-168.

Felt has now described both sexes of this midge which was mentioned in my previous paper (1930) on page 327 under *Other Gall Midges* as *Diplosis* sp.

Triommata coccotroctes, Barnes.

Barnes, Bull. Ent. Res., xxii, 1931, pp. 205-207.

Both sexes described. The adults are peculiar in possessing a dorso-median and two lateral compound eyes instead of the normal type. Reared by E. Hargreaves in 1930 from larvae preying on mealy-bug at Njala, Sierra Leone.

Olesicoccus costa-limai, Borg.

Borgmeier, Rev. de Entomologia, i, 1931, pp. 184-191.

Both sexes as well as larva and pupa described. Larvae predacious on *Pulvinaria ficus*, Hemp., in S. Paulo. Some notes on the life history are also given.

3. Gall Midges whose Larvae attack free-living Mites.*Therodiplosis persicae*, Kieffer.

Kieffer, Neue Gallmücken-Gattungen, Bitsch, 1912, p. 2; Marcellia, xi, 1912, pp. 10-11 (this is a reprint of the former, which was published separately); Genera Insectorum, fasc. 152, 1913, pp. 202-203).

Barnes, Ent. Mon. Mag., lxii, 1925, pp. 57-58.

Speyer, Nursery & Mkt. Gdn. Ind. Devpmt. Soc. Ltd., Exptl. & Res. Sta., 11th. Ann. Rept. 1925, 1926, p. 93 (*Thecodiplosis*); *op. cit.*, 12th Ann. Rept. 1926, 1927, pp. 54-55.

Male and female described very inadequately in 1912. There is a better description in *Genera Insectorum*, where it is stated that the larvae are predacious on *Tetranychus* sp. on the leaves of peach in France. In England it has been found attacking red spider (*T. telarius*) on bean and tomato at Cheshunt by Speyer and on peach at Stroud, Gloucester (H. Eltringham, 1925) and near Derby (A. Roebuck, 1925). Other records include the following:—attacking red spider on egg-plant, 1927, Cheshunt (E. R. Speyer: Barnes collection, ♂, Cecid. 851, ♂♀, Cecid. 852); red spider on Convolvulus, 1927, Turnford, Herts. (E. R. Speyer; ♂♂, Cecid. 848 and 849); and possibly specimens (♀♀, Cecid. 219 and 423) reared from larvae attacking red spider on *Arum* at Waltham Cross in 1926 received from F. W. Edwards.

Speyer (1926) states that the eggs are laid in the web spun by the mite. Pupation takes place in a white cocoon along the veins of the leaves usually on the lower surface. Speyer (1927) states that the larva is a voracious feeder on all stages of red spider in tomato houses. The larvae were first noticed in July and became more plentiful until

September, when it is too late to exert any control over the pest. Pupation takes 9 days in August. Speyer also claims that they do not seem to be killed where the foliage was sprayed with soft soap and liver of sulphur solution.

Feltiella acarinivora, Tölg.

Tölg, Neue Beitr. z. syst. Insek., ii, 1921, p. 33.

Male described, but no biological data given. This paper was published posthumously.

Feltiella acarivora, Tölg.

Keiffer, in Genera Insectorum, fasc. 152, 1913, p. 202, gives Tölg, Verh. zool.-bot. Ges. Wien, lxiii, as the reference to the original description of this species, which he states is found in Austria. No trace, however, can be found of this description, but see above under *Feltiella acarinivora*, Tölg.

Feltiella americana, Felt.

Felt, Canad. Ent., xlviii, 1916, pp. 33-34; N.Y. St. Mus. Bull., no. 202, 1918, p. 171.

Zool. Record, liii, 1916, Insecta, p. 217 (*Feltia*, undoubtedly a misprint).

Male and female described. Reared at the end of July 1915 by P. J. Parrott of the Agric. Exp. Sta., Geneva, N.Y., from larvae apparently feeding on red mites occurring on plum foliage.

Feltiella ithacae, Felt.

Felt, Ent. News, xxxvii, 1926, p. 141.

Male and female described. Reared in August 1925 by Grace H. Griswold of Cornell University from larvae probably predacious on red mites and other small forms upon the rose. It spins cocoons upon the leaves.

Feltiella tetranychii, Rübs.

Rübsaamen, Zeits. wiss. Insektenbiol., vii, 1911, pp. 280-282.

Keiffer, Genera Insectorum, fasc. 152, 1913, p. 202.

Piontkovskii [Cotton Indust.], vii, 1928, pp. 365-370 (R.A.E., A, xvi, 1928, p. 669).

This species is the generic type. Both sexes are described and figures are given of the male genitalia, female antennae, claw and entire adult. The larvae feed on red spider, *Tetranychus*, on hops, *Humulus lupulus*. They were found in August 1895 at Berlin. From larva to adult takes from 10 to 14 days. They are preyed on by *Scymnus ater* (Coccinellid).

Piontkovskii mentions "*Feltiella (Arthrocnodax) tetranychii* Rübs." as attacking an undescribed species of *Epitetanychus* on cotton in Turkestan. The mite was previously recorded as *Tetranychus telarius* he adds. It seems probable that he has made a mistake as regards the nomenclature and identity of the midge. Probably he really means *Acaroletes tetranychorum*, Kieff., which was originally called *Arthrocnodax tetranychii*, Kieff., and whose larvae are predacious on *T. telarius* in S. Russia (see under *Acaroletes tetranychorum*).

Feltiella venatoria, Felt.

Felt, J. N.Y. Ent. Soc., xxv, 1917, pp. 195-196; N.Y. Mus. Bull., no. 202, 1918, pp. 172-173.

Male and female described. Received from D. K. McMillan, Northern Illinois, presumably Chicago, in August 1916. The larvae are stated to be very efficient destroyers of *T. telarius* and other species on the leaves of elm and hollyhock.

Acaroletes tetranychorum (Kieffer).

Kieffer, Revue Russe Ent. 1907, 1908, pp. 201-202 (*Arthrocnodax tetranychii*); Marcellia, xi, 1912, p. 229 (*Acaroletes tetranychii*); Genera Insectorum, fasc. 152, 1913, p. 201 (*tetranychorum* n. nov.).

Vasilev [Cotton Indust.], iii, 1924, pp. 86-116 (R.A.E., A., xii, 1924, p. 555 (*Acaroletes tetranychii*)).

Male and larva described. Received from J. Vasilev. The larvae live on *T. telarius* in S. Russia. This species was made the type of the genus *Acaroletes* by Kieffer in 1912. Vasilev states that it is abundant throughout the cotton area from Transcaucasia to Turkestan, preying on *T. telarius*. This is probably the species Piontkovskii refers to in his paper of 1928 mentioned above under *Feltiella tetranychii*, Rübs.

Mycodiplosis acarivora (Felt).

Felt, Ent. News, xviii, 1907, p. 242 (*Cecidomyia*); N.Y. St. Mus. Bull., no. 125, 1908, p. 385, 403 (*Mycodiplosis*); Pomona Coll. J. Entom., iv, 1912, p. 756; J. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, pp. 201-203.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 213.

Male, female and larva described. Received from Frederick Maskew of S. California. The larvae were found feeding on *Tetranychus mytilaspidis* and *T. sexmaculatus*, infesting lemon leaves and fruit at Chula Vista, Cal.

Felt (1918) states that this species or a very closely allied form was reared from larvae attacking red spider on the Kentucky coffee tree, *Gymnocladus canadensis*, and on corn from lots sent for identification by L. O. Howard. In the same reference are given some general notes, made by Theodore Pergande in August 1883, on larvae of the same genus, and probably this species, which he found feeding on red spider on corn.

Mycodiplosis insularis, Felt.

Felt, Canad. Ent., xlv, 1913, pp. 305-306; J. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, p. 184.

Male, female and larva described. The larvae and white cocoons were collected at Rio Piedras, P.R., in August 1913 by Thomas H. Jones from among colonies of red spider on the leaves of *Leonotis nepetaefolia*.

Mycodiplosis macgregori, Felt.

Felt, J. Econ. Ent., viii, 1915, p. 149; N.Y. St. Mus. Bull., no. 202, 1918, p. 196.

McGregor & McDonough, U.S.D.A., Bull. 416, 1917, pp. 51-52.

Male described. It was reared by E. A. McGregor, South Carolina, from larvae attacking red spider on cotton. Apparently it resembles *A. carolina*, Felt, in general biology but appears later, even as late as December.

Mycodiplosis sp.

Larvae of this genus were found in August 1930 at Harpenden on the leaves of hollyhock, which were heavily infested with red spider and also had spots of rust on them. It is not certain whether they were feeding on the mites or rust but probably the former. Some adults were reared (♂, Cecid, 1483; ♀, Cecid, 1484; larvae, Cecid. 1617 and 1482; other specimens in alcohol tube 950).

Arthrocnodax acarisuga (Vall.).

Vallot, Mém. Acad. Sc. Dijon, 1827, pp. 95-96 (*Cecidomyia*).

Kieffer, Ann. Soc. ent. Fr., lxi, 1901, p. 333 (*Cecidomyia*): Genera Insectorum, fasc. 152, 1913, p. 156 (*Arthrocnodax*).

This the first record of a mite-eating Cecidomyid.

The larvae feed on mites (*Acarus*) on the lower side of the leaves of *Chelidonium majus* in August and September. The cocoon is to be found at the junction of the veins on the leaf.

Arthrocnodax apiphila, Felt.

Felt, New Species of Cecidomyiidae II, 1907, p. 20; N.Y. St. Mus. Bull., no. 124, 1908, p. 301, 404; Pomona Coll. J. Entom., iv, 1912, p. 756; J. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 175, 1915, pl. 2, fig. 12; *op. cit.*, no. 200, 1918, p. 150; *op. cit.*, no. 231-2, 1921, pp. 81, 87-89, figs. 4-6.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 156.

The male was described in 1907 and both sexes in 1921. It was bred in October 1907 by Burton N. Gates from larvae feeding in mite-infested material and excrement of old bee combs received from California. Dr. Felt considers that they may have been feeding on a species of *Tyroglyphus* and a red mite belonging to the GAMASIDAE which were found among the material.

This species had, according to Felt (1921), also been reared from a twig badly infested by *Pulvinaria vitis*, Linn., and from a breeding jar containing forest tent caterpillar (*Malacosoma disstria*, Hüb.) cocoons and debris received from Tacoma, Wash. It was also obtained from a jar containing *Viburnum* leaves bearing numerous blister galls. He also states that possibly *Aphanogamus floridanus*, Ashmead (Insect Life, iv, 1891, p. 123) is a parasite of this species.

Arthrocnodax carolina, Felt.

Felt, J. Econ. Ent., vi, 1913, pp. 488-489; *op. cit.*, vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 200, 1918, p. 171; *op. cit.*, no. 231-2, 1921, p. 90.

McGregor, J. Econ. Ent., vii, 1914, p. 330.

McGregor & McDonough, U.S.D.A., Bull. 416, 1917, pp. 48-51.

Male and female described from larvae eating red spider on cotton at Batesbury, S. Carolina, and reared in 1912 and 1913 by E. A. McGregor.

The earliest occurrence is at the end of April and it is abundant in the middle of May. It multiplies very rapidly in July and August when it is at its height of development. Then it becomes more scarce in September and is met with only occasionally in October. The larval stage lasts 3-5 days, the pupal state 8 days and the whole life-cycle is completed in 16 days.

McGregor claims that this midge occupies first rank among the enemies of red spider (*T. telarius*, L.=*bimaculatus*). The larvae confine their attack to the eggs. The time taken to suck one egg is from 1 to 2 minutes and the average egg consumption a day is 45.9, according to McGregor & McDonough (1917). Tables dealing with the life-history are also given in this paper. Later in the season the larvae are heavily parasitised by *Aphanogamus floridanus*, Ashmead, a Chalcidid.

This species has been collected from Virginia, N. and S. Carolina, Georgia, Florida, Alabama and Louisiana.

Arthrocnodax constricta, Felt.

Felt, J. Econ. Ent., vii, 1914, p. 481; N.Y. St. Mus. Bull., no. 231-2, 1921, p. 82.

Male and female described. Reared from garden beans infested with common red spider, *Tetranychus bimaculatus*. Collected by Thomas H. Jones, June 1913, at Rio Piedras, P.R.

Arthrocnodax mali, Kieffer.

Kieffer in Wissmann, Z. Pflanzenkr., xxxvi, 1926, pp. 103-104.

Wissmann, Z. Pflanzenkr., xxxvi, 1926, pp. 98-106.

Male, female, pupa and larva described, from Germany. Wissmann contributes the biological notes. The larvae are found from June to October, eating mites on apple leaves. The larval stage in August and September lasts a fortnight to three weeks, and the pupal stage about the same time. In captivity the larvae spin white cocoons on the under-surface of the leaves, but in the field such cocoons could not be found and probably pupation takes place in the soil. A *Platygaster* and a Pteromalid were reared from this species and *A. wissmanni*, Kieff., but it is not stated definitely whether from both species of midge or not.

Arthrocnodax occidentalis, Felt.

Felt, J. Econ. Ent., v, 1912, p. 402; Pomona Coll. J. Entom., iv, 1912, p. 756; J. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 231-2, 1921, p. 92.

Quayle, Calif. Agr. Expt. Sta. Bull., no. 234, 1912, pp. 514-515; J. Econ. Ent., vi, 1913, p. 87.

Ewing, Oregon Agr. Expt. Sta. Bull., no. 121, 1914, pp. 58-59.

Male only described. Ewing (1914) described the larvae and adult, and Quayle (1912) the egg and larva. Reared by H. J. Quayle from larvae feeding on *Tetranychus mytilaspidis*, *bimaculatus* and *sexmaculatus* in S. California. It is considered as one of the most important enemies of *T. telarius* on the Pacific coast.

The larvae feed chiefly on the eggs of the red spider. One larva consumed 165 spiders in 15 days, another 380 in 17 days. They are most abundant attacking *T. sexmaculatus*, probably because the latter live in definite colonies and their food is thus obtained without much moving about. The covering of web over the mites seems to afford protection to the larvae from parasites. Quayle (1912) figures an Hymenopterous parasite.

Arthrocnodax rutherfordi, Felt.

Felt, J. N.Y. Ent. Soc., xxiii, 1915, pp. 180-181.

Male only described. Reared by A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, in June 1914, from leaves of *Melia azedarach* infested with *Tetranychus* sp.

Arthrocnodax wissmanni, Kieffer.

Kieffer, Brotéria, xxi, 1924, pp. 89-91; in Wissmann, Z. Pflanzenkr., xxxvi, 1926, pp. 102-103.

Wissmann, Z. Pflanzenkr., xxxvi, 1926, pp. 98-106.

Brooke, Entomologist, lxiv, 1931, pp. 180-182, pl. 3.

Male, female, pupa and larva described from Germany. Wissmann gives the biological notes. The eggs, which are attached to the hairs on the underside of pear and apple leaves, are long, oval and yellowish becoming reddish. A larva was seen to destroy 13 mites within 5 minutes and then go on for more. The larvae disappeared after a shower of rain. The biology is similar to that of *A. mali*, Kieffer.

This species has been found by Miss W. M. A. Brooke attacking *Phyllocoptes schlechtendali*, Nal., near the Crystal Palace, London, on the underside of the leaves

of Cellini Pippin (Phillips Seedling) apple. This is the same species of mite as Wissmann found being attacked. This author gives biological notes and states that a mite is sucked dry in 30–45 seconds, one larvae eating 9 mites in 5 minutes.

Silvestrina farinicola, Barnes.

Barnes, Bull. Ent. Res., xx, 1929, pp. 120–122; Ann. Mag. Nat. Hist., (10) ix, 1932, p. 477.

Male and female described. Reared by G. Candura from larvae found in flour at Naples. The flour was infested by mites, and it is supposed the larvae were preying on the mites.

Lestodiplosis raphani, Barnes.

Barnes, Bull. Ent. Res., xx, 1929, pp. 119–120.

Male and female described. Reared by M. Prosper Bovien, Lyngby, from larvae found among seed of radish (*Raphanus sativum*) that had been in storage and was infested by mites (*Aleurobius*, etc.). It had been found some years previously in seed infested by *Cheyletus* but in which there were no *Aleurobius*. It occurs at irregular intervals in seed from Denmark and Germany. It is presumed that the larvae were living at the expense of the mites.

This species was also sent to me in 1932 by Mr. G. Fox Wilson. He received the larvae from a correspondent who obtained it from turnip seed grown in Lincolnshire, 1930 harvest. The adult midges emerged between 6th and 22nd June 1932. The correspondent points out that they (the larvae) seem to be more prevalent in seed that is badly attacked by the flour mite. He adds "Stored seed (Brassicas) harvested after a good season and ideal conditions are rarely attacked to any extent by these pests." Mr. A. Roebuck (1932) has also sent me this species from stored radish seed at Leicester. He stated that the cocoons were to be found in large numbers on the outside of the sacks which contained seed infested with mites.

Lestodiplosis woeldickii, Contarini.

Contarini, Atti Ateneo Veneto, iii, 1839, pp. 122–130 (*Cecidomya*).

Kieffer, Bull. Soc. Hist. Nat. Metz, (2), viii, 1898, p. 40 (*Lestodiplosis*); Ann. Soc. ent. Fr., lxi, 1901, p. 333; Genera Insectorum, fasc. 152, 1913, p. 198.

Larva, male and female described and illustrated in colour. Reared from larvae found on the feathers of stuffed birds in Italy, probably feeding on mites.

Lestodiplosis sp.

Garmon, Conn. Agric. Expt. Sta. Bull., no. 225, 1921, p. 241.

Larvae of *Lestodiplosis* have been found feeding on *Rhizoglyphus hyacinthi*, Banks, in Connecticut.

Diplosis acarivora, Zehntner.

Zehntner, Arch. Java Suikerind., v, 1901, 17 pp.

Keuchenius, Meded. v. h. Besoekisch Proefstation, Djember, no. 16, 1915, p. 63 (R.A.E., A., iii, 1915, p. 648).

Dammerman, The Agricultural Zoology of the Malay Archipelago, 1929, p. 346.

It has not been possible to see Zehntner's original description. The larvae feed on *Tetranychus exsicicator* on sugar-cane leaves in Java. Keuchenius mentions a Cecidomyid as preying on *Pseudococcus bicaudatus*, Keuch., in Java and says it may be this species. The present writer thinks this improbable.

Cecid. sp.

Kieffer, Ann. Soc. ent. Fr., lxi, 1901, pp. 334-335.

Kieffer here gives a note on the larva of a gall midge which he found among mites and their dried skins on the leaves of weeping elm in August 1894.

4. Gall Midges whose Larvae are known to, or probably, attack gall-inhabiting Mites.

Arthrocnodax abdominalis, Felt.

Felt, Ent. News, xxii, 1911, pp. 128-129 (*Endaphis*); J. Econ. Ent., vii, 1914, p. 458 (*Arthrocnodax*); N.Y. St. Mus. Bull., no. 231-2, 1921, p. 85 (*Arthrocnodax*).

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 155 (*Feltodiplosis*).

Male and female described. Received from C. H. T. Townsend, Piura, Peru, from cotton leaves badly infested with galls containing mites. Felt (1914) noted red spider as the prey of the larvae.

Arthrocnodax americana, Felt.

Felt, Ent. News, xxii, 1911, p. 129 (*Endaphis*); N.Y. St. Mus. Bull., no. 202, 1918, p. 92 (*Endaphis*).

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 155 (*Feltodiplosis*).

Female only described. Reared in September 1910 from what appeared to be galls of *Eriophyes fraxinivorus*, Nal. (1909), on *Fraxinus velutina* collected by Dr. R. E. Kunze, Arizona, in the August. It appears that the correct generic position is as placed above.

Arthrocnodax clematidis, Marchal.

Marchal, Mém. Soc. zool. France, x, 1897, pp. 23-24.

Kieffer, Bull. Soc. Hist. nat. Metz, (2), viii, 1898, p. 29; Genera Insectorum, fasc. 152, 1913, p. 156.

Male and female described and figured. The larvae live in the galls of *Epitrimerus heterogaster*, Nal. (1890), on *Clematis cirrhosa* at Blidah, Algeria.

Arthrocnodax coryligallarum, T. T.

Targioni-Tozzetti, Bull. Soc. ent. ital., xviii, 1886, pp. 422-425 (*Diplosis*).

Kieffer, Bull. Soc. Hist. nat. Metz, (2), viii, 1898, p. 29 (*Arthrocnodax*); Ann. Soc. ent. Fr., lxi, 1901, p. 334 (*Diplosis*); Genera Insectorum, fasc. 152, 1913, p. 156.

Stefani, Ann. R. Staz. Speriment. Agrum. Fruttic., Acireale, iv, 1916-18, pp. 171-186 (R.A.E., A., vii, 1919, p. 413.)

Bagnall & Harrison, Ent. Rec., xxxvi, 1924, p. 37.

Barnes, Ann. Rept. Ent. Dept., 1925-6, S.E. Agric. Coll. Wye, Kent, 1926, p. 17.

Boselli, Boll. Lab. Zool. Portici, 1928, p. 249.

Larva, male and female described. Reared from larvae in big bud galls of *Eriophyes avellanac*, Nal. (1889), on *Corylus avellana* in Italy. Stefani noted *Arthrocnodax* spp. in a list of enemies of this mite. Bagnall & Harrison have found the yellow larvae of this species in Somerset and Shropshire, and Barnes has found it in Kent.

Arthrocnodax fraxinella, Meade = ? *Cecidomyia minuta*, Winn.

Meade, Ent. Mon. Mag., xxv, 1888, p. 77 (*Diplosis*).

Kieffer, Bull. Soc. Hist. nat. Metz, (2) ix, 1899, p. 14 (*Arthrocnodax*); Genera Insectorum, fasc. 152, 1913, p. 156.

Bagnall & Harrison, Trans. Ent. Soc. London 1917, 1918, p. 389.

Male and female described. The larvae were found as inquilines in flower galls, the cauliflower ash-gall, of *Eriophyes fraxinivorus*, Nal. (1909), on *Fraxinus excelsior* by Dr. Chapman in August 1887 in England. Kieffer (1900) states that the larvae are undoubtedly predacious on the mites.

Arthrocnodax gemmarum, Kieffer.

Kieffer, Feuilles Jeunes Natural. Paris, xxvi, 1895, p. 9; Bull. Soc. Hist. nat. Metz, (2) viii, 1898, p. 29; Genera Insectorum, fasc. 152, 1913, p. 156.

Male and female described. The larvae are predacious on *Eriophyes stenaspis*, Nal. (1891), in deformed buds and folds of leaves of beech in Lorraine.

Arthrocnodax incana, Rübs.

Rübsaamen, Verh. naturh. Ver. Preuss. Rheinl. Bonn, xlvii, 1890, pp. 20-21 (*Diplosis*); Wien. ent. Ztg., xiv, 1895, pp. 191-193 (*Arthrocnodax*).

Kieffer, Bull. Soc. Hist. nat. Metz, (2) viii, 1898, p. 29; Genera Insectorum, fasc. 152, 1913, p. 156.

Female only described. Reared from gall of *Dasynura populeti*, Rübs., on *Populus tremula* in Germany. Probably a mite eater.

Arthrocnodax meridionalis, Felt.

Felt, Ent. News, xxiii, 1912, pp. 176-177; N.Y. St. Mus. Bull., no. 231-2, 1921, p. 85.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 156.

Larva, male and female described. Reared in May 1911 from open *Eriophyes* galls on the leaves of *Ruellia tuberosa*, Linn., doubtless preying upon the mites, by W. H. Patterson, St. Vincent, W.I.

Mr. Patterson, according to Felt (1912), obtained a similar, if not identical, species in May 1911 from *Eriophyes* galls on the leaves and bracts of *Lepidagnathis alopecuroidea*. He reared the same species in April 1911 from galls of *Eriophyes gossypii*, Banks (1904), on Sea Island cotton and also from mite galls on the leaves of a species of *Eupatorium*.

Arthrocnodax peregrina, Winn.

Winnertz, Linn. Ent. Stettin, viii, 1853, p. 252 (*Diplosis*).

Kieffer, Bull. Soc. Hist. nat. Metz, (2) viii, 1898, p. 30 (*Arthrocnodax*); Ann. Soc. ent. Fr., lxi, 1901, pp. 333-334 (*Diplosis*); Genera Insectorum, fasc. 152, p. 156 (*Arthrocnodax*).

Male described. Reared from larvae living in mite galls on *Prunus spinosa* and *Salix aurita* in Germany and Austria. Pupation takes place in the soil.

Arthrocnodax rhoina, Felt.

Felt, N.Y. St. Mus. Bull., no. 124, 1908, p. 404; *op. cit.*, no. 200, 1918, p. 159; *op. cit.*, no. 231-2, 1921, pp. 90-91.

Male described. Reared in August 1907 from curled sumac (*Rhus*) leaves at Albany, N.Y. Probably the larvae prey on a plant mite.

Arthrocnodax sambucifolia, Felt.

Felt, N.Y. St. Mus. Bull., no. 124, p. 404; *op. cit.*, no. 200, 1918, p. 188; *op. cit.*, no. 231-2, 1921, p. 91.

Larva and male described. Reared from rolled elder leaves (*Sambucus canadensis*) in September 1907 at Albany, N.Y. Felt states that it is probably predacious.

Arthrocnodax vitis, Rübs.

Rübsaamen, Wien. ent. Ztg., xiv, 1895, pp. 189-193; Z. wiss. Insektenbiol., ii, 1906, p. 234.

Kieffer, Bull. Soc. Hist. nat. Metz, (2) viii, 1895, p. 30; Genera Insectorum, fasc. 152, 1913, p. 156.

Larva, male and female described and figured. Recorded as living on *Eriophyes vitis*, Nal. (1890), on vine.

Lestodiplosis tarsonemi, Rübs.

Rübsaamen, Ent. NachrBl., Berlin, xxi, 1895, p. 184.

Kieffer, Bull. Soc. Hist. nat. Metz, (2) viii, 1898, p. 40; Ann. Soc. ent. Fr., lxix, 1901, p. 335; Genera Insectorum, fasc. 152, 1913, p. 198.

Male and female described together. The larvae were found in Germany in a swelling on the stem of *Arundo phragmites* which was inhabited by *Tarsonemus* sp.

Cecid. sp.

Warburton & Embleton (J. Linn. Soc. Zool., xxviii, 1902, p. 375) refer to the presence of what is claimed to be Cecidomyid larvae in "big buds" of black currant caused by *Eriophyes ribis* (Westw.) Nal. (1893). Massee (Bull. Ent. Res., xviii, 1928, p. 302) refers to this record.

5. Gall Midges whose Larvae may feed on Mites.

The larvae of certain gall midges have been known for a long time to live in the galls of mites. They may be living on the mites or as scavengers in the galls or simply as inquilines.

Kieffer (Ann. Soc. ent. Fr., lxix, 1901, pp. 333-335) refers to several old records. He states that the first observation of this nature was by Réamur, who found Cecid larvae in the corniculate galls of lime (*Tilia*). Bremi (Denkschr. allgem. schweiz. Ges. f. ges. Naturwiss. Neuenburg, xi, 1847, p. 30) indicated such larvae for the *Erineum* of *Poterium sanguisorbae* and in the straight margin leaf-roll of *Salix alba*. Kieffer (*loc. cit.*) quotes H. Loew as finding larvae in red galls the size of a grain of millet on the leaves of *Salix*. Winnertz, according to Kieffer (*loc. cit.*), states that larvae of midges are to be found in the galls of *Eriophyes thomasi*, Nal. (1889), on *Thymus serpyllum*, as Vallot and H. Loew had already recorded and as Perris (Ann. Soc. ent. Fr., x, 1871, p. 178) and Fr. Loew (Verh. zool.-bot. Ges. Wien, xxiii, 1874, p. 159) again recorded later. Perris (*loc. cit.*, p. 179) also gives four other examples of Cecid larvae living in Phytoptid galls on *Origanum*, *Lysimachia*, *Mentha rotundifolia* and *Trifolium subterraneum*. Von Frauenfeld (Verh. zool.-bot. Ges. Wien, xv, 1865, p. 898) recorded them in Phytoptid galls of *Euonymus*. Fr. Loew (*loc. cit.*) further recorded them in the galls of *Eriophyes galiobius*, Can. (1891), on *Galium verum*, of *Erineum alneum* on *Alnus glutinosa*, and of *Erineum betulinum* on *Betula*. He figured a larva which can be recognised, according to Kieffer (*loc. cit.*), as an *Arthrocnodax* species.

Rübsaamen (Wien. ent. Ztg., xiv, 1895, pp. 191-193) recorded finding larvae, belonging to the genus *Arthrocnodax*, predacious on *Eriophyes spiraeae*, Nal. (1895),

on *Spiraea crenifolia* in the Southern Urals. He also states that he found similar larvae on the leaves of *Artemisia camphorata* and *Viburnum lantana*.

The following midges have been reared from mite galls and may be predacious on the mites.

Microdiplosis zambezensis, Tav.

Tavares, Brotéria, vii, 1908, pp. 155-156.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 210.

Male and female described and figured as the generic type. Reared from various leaf-galls due to Phytotids in Mozambique, Africa.

Hyperdiplosis producta, Felt.

Felt, Ent. News, xxiii, 1912, p. 177; N.Y. St. Mus. Bull., no. 182, 1918, p. 182; *op. cit.*, no. 231-2, 1921, p. 125.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 211.

Male and female described. Reared by W. H. Patterson, St. Vincent, W.I., from presumably mite galls in the inflorescence of *Stachytarpheta jamaicensis*.

The following midges were described from caught specimens and nothing is known about their life-history. It seems likely, however, that their larvae are predacious on mites.

(1) *Arthrocnodax acerina*, *cincta*, *fenestra*, *filicis*, *fraxini*, *incisa*, *obscura*, *rufa* and *sylvestris*, all of Felt.

References to their original descriptions and new descriptions are given by Felt, N.Y. St. Mus. Bull., no. 231-2, 1921, pp. 83-90. These are all American species and a specific key has been constructed (*op. cit.*, pp. 81-83).

(2) *Arthrocnodax minuta*, Winn. (? = *fraxinella*, Meade).

Winnertz, Linn. Ent., Stettin, viii, 1853, p. 250 (*Diplosis*).

(3) *Silvestrina minima*, Rübs.

Rübsaamen, Berlin ent. Zeits., xxxvi, 1891, pp. 50-52 (*Diplosis*).

The following species feeds on the excreta of mites.

Lestodiplosis (*Coprodiplosis*) *entomophila*, Perris.

Perris, Mém. Soc. Sc. Liège, x, 1855, p. 274 (*Cecidomyia*).

Kieffer, Bull. Soc. Hist. nat. Metz, (2) viii, 1898, p. 40 (*Coprodiplosis*); Ann. Soc. ent. Fr., lxi, 1901, pp. 336-337 (*Lestodiplosis*); Genera Insectorum, fasc. 152, 1913, p. 198 (*Coprodiplosis*).

Male and larva described. Reared from larvae found in France living on the excreta of mites attacking dried and pinned insects.

The following two species may have been feeding on mites.

Silvestrina ficorum, Barnes (Ann. Mag. Nat. Hist., (10) ix, 1932, p. 476) reared from fermenting dried figs in Algeria.

Silvestrina coprae, Felt (Philipp. J. Sci., xiv, 1919, pp. 291-292) originally reared from copra at Luzon, P.I. and more latterly from copra at Banting in the Malay Peninsula (Barnes, Ann. Mag. Nat. Hist., (10) ix, 1932, p. 479).

6. List of Plants on which Mites are attacked by Gall Midge Larvae.

A. FREE-LIVING MITES.

Plant and Mite	Midge	Country
<i>Althaea</i> (<i>T. telarius</i>)	<i>Feltiella venatoria</i> , Felt	U.S.A.
„ (red spider)	<i>Mycodiplosis</i> sp.	England
Apple, see under <i>Pyrus malus</i>		
<i>Arum</i> (<i>T. telarius</i>)	? <i>Therodiplosis persicae</i> , Kieff.	England
Bean, see under <i>Vicia faba</i>		
Bean, Garden (<i>T. bimaculatus</i>)	<i>Arthrocnodax constricta</i> , Felt	Porto Rico
<i>Chelidonium majus</i> (<i>Acarus</i>)	<i>Arthrocnodax acarisuga</i> , Vall.	France
Citrus spp. (<i>T. telarius</i> , <i>mytilaspidis</i> , <i>bimaculatus</i> , <i>sexmaculatus</i>)	<i>Arthrocnodax occidentalis</i> , Felt	U.S.A.
<i>Citrus medica</i> var. <i>limonum</i> (<i>T. mytilaspidis</i> , <i>sexmaculatus</i>)	<i>Mycodiplosis acarivora</i> , Felt	U.S.A.
<i>Convolvulus</i> (<i>T. telarius</i>)	<i>Therodiplosis persicae</i> , Kieff.	England
Corn (red spider)	<i>Mycodiplosis acarivora</i> , Felt	U.S.A.
Cotton, see under <i>Gossypium</i>		
Egg plant, see under <i>Solanum melongena</i>		
Elm, see under <i>Ulmus</i>		
<i>Gossypium</i> (<i>T. telarius</i>)	<i>Acaroletes tetranychorum</i> , Kieff.	S. Russia
„ (<i>T. telarius</i>)	<i>Mycodiplosis macgregori</i> , Felt	U.S.A.
„ (<i>T. telarius</i>)	<i>Arthrocnodax carolina</i> , Felt	U.S.A.
<i>Gymnocladus canadensis</i> (red spider)	<i>Mycodiplosis acarivora</i> , Felt	U.S.A.
Hollyhock, see under <i>Althaea</i>		
Hop, see under <i>Humulus lupulus</i>		
<i>Humulus lupulus</i> (<i>Tetranychus</i> sp.)	<i>Feltiella tetranychii</i> , Rübs.	Germany
<i>Hyacinthus</i> sp. (<i>Rhizoglyphus hyacinthi</i> , Banks)	<i>Lestodiplosis</i> sp.	U.S.A.
<i>Leonotis nepetaefolia</i> (red spider)	<i>Mycodiplosis insularis</i> , Felt	Porto Rico
<i>Melia azedarach</i> (<i>Tetranychus</i> sp.)	<i>Arthrocnodax rutherfordi</i> , Felt	Ceylon
Peach, see under <i>Prunus persicae</i>		
Pear, see under <i>Pyrus communis</i>		
Plum, see under <i>Prunus domestica</i>		
<i>Prunus domestica</i> (red mites)	<i>Feltiella americana</i> , Felt	U.S.A.
<i>Prunus persicae</i> (<i>T. telarius</i>)	<i>Therodiplosis persicae</i> , Kieff.	France, England

A. FREE-LIVING MITES—(continued).

Plant and Mite	Midge	Country
<i>Pyrus communis</i> (<i>Phyllocoptes schlechtendali</i> , Nal.)	<i>Arthrocnodax wissmanni</i> , Kieff.	Germany
<i>Pyrus mali</i> (<i>Phyllocoptes schlechtendali</i> , Nal.)	" "	Germany, England
" (mites)	<i>Arthrocnodax mali</i> , Kieff.	Germany
<i>Rosa</i> (red mites)	<i>Feltiella ithacae</i> , Felt	U.S.A.
<i>Saccharum officinarum</i> (<i>T. exsicicator</i>)	<i>Diplosis acarivora</i> , Zehnt.	Java
<i>Solanum lycopersicum</i> (<i>T. telarius</i>)	<i>Therodiplosis persicae</i> , Kieff.	England
<i>Solanum melongena</i> (<i>T. telarius</i>)	" "	England
Sugar-cane, see under <i>Saccharum officinarum</i>		
Tomato, see under <i>Solanum lycopersicum</i>		
<i>Ulmus</i> (<i>T. telarius</i>)	<i>Feltiella venatoria</i> , Felt	U.S.A.
" (mites)	<i>Cecid.</i> sp.	France
<i>Vicia faba</i> (<i>T. telarius</i>)	<i>Therodiplosis persicae</i> , Kieff.	England
Beehive debris (<i>Tyroglyphus</i>)	<i>Arthrocnodax apiphila</i> , Felt	U.S.A.
Flour (mites)	<i>Silvestrina farinicola</i> , Barnes	Italy
Seed of <i>Raphanus sativa</i> (<i>Aleurobius</i>)	<i>Lestodiplosis raphani</i> , Barnes	Denmark, England
Stuffed birds (mites)	<i>Lestodiplosis woeldickii</i> , Cont.	Italy

B. GALL-INHABITING MITES.

Plant and Mite	Midge	Country
<i>Arundo phragmites</i> (<i>Tarsonemus</i>)	<i>Lestodiplosis tarsonemi</i> , Rübs.	Germany
Ash, see under <i>Fraxinus excelsior</i>		
Beech, see under <i>Fagus</i>		
Black Currant, see under <i>Ribes nigrum</i>		
<i>Clematis cirrhosa</i> (<i>Epitrimerus heterogaster</i> , Nal., 1890)	<i>Arthrocnodax clematidis</i> , Marchal	Algeria
<i>Corylus avellana</i> (<i>Eriophyes avellanae</i> , Nal., 1889)	<i>Arthrocnodax coryligallarum</i> , T.-T.	Italy, England
Cotton, see under <i>Gossypium</i>		
<i>Eupatorium</i> sp. (mite leaf gall)	? <i>Arthrocnodax meridionalis</i> , Felt	St. Vincent, W.I.
<i>Fagus</i> (<i>Eriophyes stenaspis</i> , Nal., 1891)	<i>Arthrocnodax gemmarum</i> , Kieff.	Lorraine

B. GALL-INHABITING MITES—(continued).

Plant and Mite	Midge	Country
<i>Fraxinus excelsior</i> (<i>Eriophyes fraxinivorus</i> , Nal., 1909)	<i>Arthrocnodax fraxinella</i> , Meade	England
<i>Fraxinus velutina</i> (<i>Eriophyes fraxinivorus</i> , Nal., 1909)	<i>Arthrocnodax americana</i> , Felt	U.S.A.
<i>Gossypium</i> (leaf galls)	<i>Arthrocnodax abdominalis</i> , Felt	Peru
<i>Gossypium barbadense</i> (<i>Eriophyes gossypii</i> , Banks, 1904)	? <i>Arthrocnodax meridionalis</i> , Felt	St. Vincent, W.I.
Hazel, see <i>Corylus avellana</i>		
<i>Lepidagnathis alopecuroidea</i> (<i>Eriophyes</i> galls)	? <i>Arthrocnodax meridionalis</i> , Felt	St. Vincent, W.I.
<i>Populus tremula</i> (mites in gall of <i>D. populeti</i> , Rübs.)	<i>Arthrocnodax incana</i> , Rübs.	Germany
<i>Prunus spinosa</i> (mite galls)	<i>Arthrocnodax peregrina</i> , Winn.	Austria, Germany
<i>Rhus</i> (probably mites in curled leaves)	<i>Arthrocnodax rhoina</i> , Felt	U.S.A.
<i>Ribes nigrum</i> (<i>Eriophyes ribis</i> (Westw.), Nal., 1893)	Cecid. sp.	England
<i>Ruellia tuberosa</i> (<i>Eriophyes</i>)	<i>Arthrocnodax meridionalis</i> , Felt	St. Vincent, W.I.
<i>Salix aurita</i> (mite galls)	<i>Arthrocnodax peregrina</i> , Winn.	Austria, Germany
<i>Sambucus canadensis</i> (probably mites in rolled leaves)	<i>Arthrocnodax sambucifolia</i> , Felt	U.S.A.
<i>Viburnum</i> (blister galls)	<i>Arthrocnodax apiphila</i> , Felt	U.S.A.
<i>Vitis</i> (<i>Eriophyes vitis</i> , Nal., 1890)	<i>Arthrocnodax vitis</i> , Rübs.	Germany



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1928

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Aedes (Ochlerotatus) vigilax, Skuse, ♀.

SOME ECOLOGICAL FACTORS INVOLVED IN THE DISPERSAL OF MOSQUITOS IN QUEENSLAND.

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(PLATE VI.)

The presence of adult mosquitos in areas where there is apparently no water is very puzzling. It is not unreasonable to take the view that when mosquitos are found in any locality in large numbers, their breeding-places are not far distant, even if at times they appear to be obscure. Similar phenomena have been observed in most parts of the world. Certain species of salt-water marsh mosquitos are, however, to be judged from a different viewpoint, for they migrate inland not merely when they are being produced in overwhelming numbers, but when their immediate environmental conditions become unfavourable; even certain species of fresh-water swamp mosquitos show similar characteristics though to a minor degree.

***Aedes (Ochlerotatus) vigilax*, Skuse (Pl. vi).**

Aedes vigilax is the chief long distance mosquito in Australia and it outnumbers any other pest mosquito in the coastal areas. In Southern Queensland, visitations of hordes of this mosquito occur mainly during the prevalence of north-westerly winds and directly after the king tides of June and December. In summer the north-westerly wind is relatively infrequent, and is hot and dry during the day-time, and migrations of mosquitos only take place when greater humidity commences to settle down as an oppressive pall over the community. The north-easterly wind, on the other hand, is moist, but blowing as it does from the sea can only bring in mosquitos if the breeding-grounds are in direct line to the north-east of any particular locality. Northerly winds tend to bring up storms, which may carry mosquitos, provided that the winds sweep over their breeding-places.

A. vigilax is apparently a very strong flier and its presence inland many miles away from its breeding-grounds seems to be evidence of this. Its distribution over large tracts of country during the height of the summer is so general that it gives rise to the belief that the presence of this species is evidence of the failure of anti-mosquito control measures, where such are in practice. It is found inland at distances varying from one to sixty miles or more. Migrations take place usually during high barometric periods, temperature and humidity being important contributing factors. On account of the enormous hordes bred on our foreshores, only a small proportion of them can possibly hope, in their immediate neighbourhood at all events, to obtain blood from warm-blooded animals, and so the remainder are driven to seek fresh hunting-grounds. In summer *A. vigilax* occurs in prodigious numbers in Moreton Bay, and the ships passing to and fro are not infrequently besieged by them. Dr. T. L. Bancroft recounts how he had to go to the Bay at night in order to board a big steamer which was twenty miles further out than the Pile Light House at the mouth of the Brisbane River. When in the captain's cabin he noticed that mosquitos were plentiful and being interested caught and identified a number of them, which proved to be *A. vigilax*. At the time Dr. Bancroft thought that the ship had brought the mosquitos along with it, but was told by the officers that the mosquitos had only come aboard a short time before, hence the surmise that the creatures had been blown over from the islands in the Bay seemed justified.

Its principal breeding-places are in shallow water-holes containing stagnant salt water, rarely of greater depth than about 2 to 3 feet. It is such a prolific mosquito that numerous broods are reared quickly between periods of one high tide and another, or before the shallow water-holes dry up.

Though it seems to prefer brackish water for rapid development, its larvae swarm in pools which have become highly concentrated by evaporation, provided that the food factor is not interfered with. A good deal of misapprehension exists in the public mind with regard to tidal creeks and mangrove swamps, as suitable breeding-places, but it must be remembered that *A. vigilax* does not breed in such localities, larvivoracious fish being far too numerous. Sometimes, but very rarely, it is found breeding in fresh water when salt or brackish is not available; in such instances it is associated with other purely fresh-water mosquitos, of which *Culex annulirostris*, Skuse, and *Anopheles annulipes*, Walker, are the most frequent. In salt water it is associated with *Mucidus alternans*, Westw., *Culex sitiens*, Wied., and even *Anopheles annulipes*. *C. sitiens* is a particularly plentiful salt-water breeder along portions of our foreshores in summer but does not appear to be migratory, nor does it travel far for its blood supply.

It is during the prevalence of the summer rains that *A. vigilax* becomes so intensely active, and millions of eggs are deposited not merely upon salt water itself but also upon damp places subject to subsequent flooding. These eggs can remain in a state of desiccation for considerable periods, a portion of them hatching with the first summer rain, the remainder subsequently. The eggs laid in batches of about 70-80 on damp spots are often carried for some distance on the incoming tide and deposited in isolated water-holes left by the receding tide.

This mosquito often appears in localities situated far from its original home waters with remarkable suddenness and disappears completely after a lapse of approximately three days with surprising regularity. It is, therefore, surmised that having achieved the object for which it migrated, it returns again to its original salt-water breeding-grounds. During the periods of migration *A. vigilax* together with other pest mosquitos will often follow cattle and horses for miles.

In Brisbane the winter is passed mainly in the egg stage, there being no evidence to show that the adults survive the unfavourable winter conditions, though the species continues to breed throughout the winter months in the warmer parts of Queensland.

Bruce Mayne,¹ speaking of biting tests conducted with *Culex fatigans* says that "biting does not occur at relative humidities under 52 per cent." This coincides with our experience of *A. vigilax*. Though a vicious biter, it bites only under ideal atmospheric conditions. It avoids direct sunlight, and though often active in the early hours of the morning it will disappear with the increased temperature and reduced humidity as the day advances. In the coastal areas of the Australian bush, where shade and humidity are favourable, *A. vigilax* will bite at any time, but avoids open country. In the suburbs of Brisbane it bites mainly at sundown and keeps up its activity only whilst the humidity is favourable.

Some carefully kept records seem to show that *A. vigilax* does not embark upon extensive migrations unless the humidity is well over a percentage of 60 with a steady rise towards 90 or even 95 per cent. after the hours of midnight, thus bearing out in some measure Bruce Mayne's¹ more definite observations with regard to those mosquitos tested by him in India. The observations of Necheles² on the causes of night activity in some insects are well worth consideration in this respect.

Mucidus alternans, Westw.

Mucidus alternans occurs during the greater part of the summer in Queensland. It breeds generally in association with *Aedes vigilax*, its larvae being predatory on

those of its associated mosquitos. On days with an increasingly high barometric pressure, when *A. vigilax* commences to migrate, *Mucidus* also moves simultaneously and appears at considerable distances from its ordinary salt-water breeding-places; but if it migrates it does so only in summer. It is never so plentiful as *A. vigilax*, nor is it entirely restricted to salt water. In Queensland it is to be found at distances up to about 80 miles from the sea, and there it breeds in fresh water to a limited degree only. In the Murrumbidgee Irrigation Area of New South Wales, however, it occurs in overwhelming numbers, breeding under the most favourable conditions, with suitable food all around it in the ditches draining the rice-fields. Here it is sometimes found in association with *Culex annulirostris* and *Anopheles annulipes*, being predatory upon the larvae of both; but if the larvae of other species are not available it will prey upon its own species as a last resource.

The adults are clumsy and bite mainly at sundown. Whilst *A. vigilax* will not as a rule enter human habitations of its own volition, *Mucidus alternans* shows no aversion to coming inside habitations, but never frequents them for long.

Eggs are laid singly in batches up to about 100 and usually hatch within 5 days. The egg is a comparatively large one possessing a prominent micropyle. When freshly laid it is of a pearly colour, which darkens somewhat with age. The period of development varies with atmospheric conditions and food supply; under ideal conditions larvae are capable of reaching the pupal stage in 9 or 10 days. The pupal stage lasts 3 to 5 days and males will emerge after 3 days, but during periods of high barometric pressure every phase of development is hastened.

Prevalence of Mosquitos in Areas devoid of Water.

It is a common occurrence in Australia to find bush mosquitos, not in themselves migratory, in overwhelming numbers in districts where apparently there is no water; it is a matter of some difficulty to account for these in areas where the breeding-places remain obscure, and one is justified, in many instances, in supposing that these mosquitos are blown into dry regions. This latter statement, however, does not apply to mosquitos breeding in tree-cavities. *Aedes notoscriptus* is known to be very prolific in apparently waterless regions and its presence in large tree-cavities holding a considerable amount of water doubtless accounts for the prodigious numbers of active adults in those localities at certain seasons of the year.

With regard to other mosquitos extreme localisation offers the most suitable solution to the difficulty, and a large number of active mosquitos generally indicates local opportunities for breeding.

More arid regions, however, seem to provide some distinct attraction for certain types of sylvan mosquitos, and one is inclined to believe that in these exist the necessary physiological conditions to which the particular species may have become accustomed; moreover it is a matter of common knowledge that such mosquitos are more intent on blood than those apparently more favourably situated.

Dry areas are frequently covered with a greater growth of vegetation, much of it consisting of low shrubs, which provide better protection to mosquitos for the fulfilment of their life processes than the more open lands. This struck the author very forcibly on the borders of the Irrigation Area of New South Wales. In the unirrigated areas low bushes abound, creating apparently more favourable resting and mating grounds than the actual watered areas appear to do. Domesticated and wild animals and birds which hide in the dry areas during the day time, roam about at night seeking suitable drinking grounds, and it is not at all unlikely that many of these animals carry back with them hordes of mosquitos for long distances from their breeding-grounds; and then there is the enhanced humidity, which always obtains amongst trees and which may be an additional attraction.

Extreme localisation, too, probably explains the prevalence of large numbers of mosquitos during dry seasons when there is practically no water to be seen anywhere. Such conditions are extremely common in the Queensland bush and have been observed in other parts of the world; in Africa, for instance, conditions exist towards the end of the dry season just before the rains when there is no water in pools or ponds, but when mosquitos are worse than at other times.

It is asserted that there is no necessity for mosquitos to travel far from their breeding-places so long as the necessary physiological conditions are fulfilled, but out in the open we find types of sylvan mosquitos that travel for considerable distances in search of blood. One of the most striking cases which came under my notice was the regular dispersal of mosquitos for considerable distances from their breeding-places on the Murrumbidgee Irrigation Area of New South Wales. During the early growth of the rice, I was able to walk all over the rice paddocks at any time of the day without encountering a single adult mosquito, and yet punctually at sundown some half a dozen species would appear as if by magic from nowhere and commence to bite most viciously. Shelter there was none, and the nearest tree was almost three-quarters of a mile away, and no breeding-places could be located nearer than half a mile.

On these occasions *Culex annulirostris*, Skuse, was by far the commonest mosquito. *Anopheles annulipes*, Walker, was exceptionally plentiful. *Mansonia uniformis*, Theo., *Mucidus alternans*, Westw., and *Aedes theobaldi*, Taylor, were species equally active at that time. These mosquitos keep up their biting practically throughout the earlier portions of the night but entirely disappear by sunrise. Adult movements of most pestiferous sylvan mosquitos are rapid and determined, they travel considerable distances in search of blood, working actively at sunrise for a short period and then again at sundown more actively still. Such mosquitos have an instinctive dislike to direct sunlight and avoid it during the warmer portions of the day. Shelter, therefore, becomes a necessity to the species here referred to, and it is significant to note that where large tracts of timber have been cut down these species have also disappeared.

Summary and Conclusions.

(1) *Aedes vigilax* migrates for long distances and together with *Mucidus alternans* disperses over considerable areas under favourable physiological conditions.

(2) Migrations are only undertaken when suitable winds make dispersal possible; north-westerly winds distribute, under suitable atmospheric conditions, untold numbers of *A. vigilax* all along our foreshores.

(3) In summer the appearance in large numbers of both *A. vigilax* and *Mucidus alternans* heralds the approach of a storm.

(4) The presence of mosquitos found in wide areas in Queensland apparently devoid of water may be explained: (a) By the existence of breeding facilities in tree-cavities and similar breeding-places not visible to a casual observer; (b) by the prevalence of suitable carrying winds by which mosquitos are blown for short or long distances from their native breeding-places; (c) by extreme localisation of mosquitos breeding in small quantities of water mostly inaccessible to the casual observer.

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EXPERIMENTS IN THE CONTROL OF TSETSE FLY. PART II.

By LL. LLOYD, D.Sc.; H. M. O. LESTER, B.Sc., M.R.C.S., L.R.C.P.;

A. W. TAYLOR, M.Sc.; and A. S. THORNEWILL, B.A.

(2 MAPS.)

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1. Introduction.

The following report continues the account of the field experiments carried out by the Tsetse Investigation in Northern Nigeria. These experiments comprised clearing, control of grass burning, and exclusion of game from a tsetse focus by a wire fence. The Sherifuri experimental area is described and notes of the climatic conditions are given in previous reports.^{1,2,3} These give an account of the work up to the end of May 1926. The present report carries the record of the work up to the end of October 1929; since then no further experimental clearing has been done as the Tsetse Investigation has been more concerned with laboratory research into problems of trypanosomiasis and with the treatment and control of sleeping sickness. The observations of the Forestry Officer (A. S. Thornehill) during 1930 and part of 1931 are included in this report.

During the period under review, there were various changes in the working party. Dr. W. B. Johnson left the Investigation in October 1928 and Dr. P. H. Rawson in March 1929. Dr. H. M. O. Lester joined the Investigation in September 1926 and Mr. A. W. Taylor was appointed Junior Entomologist in August 1927. Capt. A. S. Thornehill, Assistant Conservator of Forests, was attached to the Tsetse Investigation in February 1928. He returned to duty with the Forestry Department in May 1929, but subsequently rejoined the Investigation in November of the same year. From December 1927 until October 1929 much of the work of supervising clearing operations was carried out by Administrative officers especially seconded for the purpose.

The first two sections of the report deal with the main Sherifuri clearings and their effect on *Glossina morsitans* and *G. tachinoides*. The Matyoro experimental area, which lies 110 miles south-east of Sherifuri, is dealt with in a subsequent section. Other sections deal with the application of clearing methods to sleeping sickness areas and with deferred grass burning.

2. Sherifuri Area.

The experimental area at Sherifuri consists of about 72 square miles of country with about 75 miles of meandering water-courses. The accompanying chart gives some idea of the forest vegetation types which are met with in the area. The seven types of vegetation enumerated are naturally inter-dependent and merge one into another, many genera and species being found in more than one type. The chart,

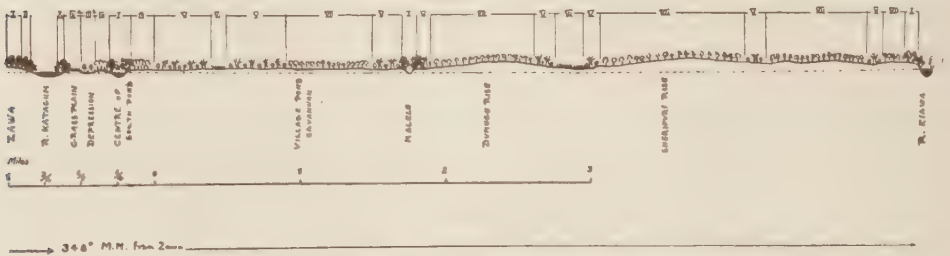


Fig. 1. Sherifuri Arboreal Vegetation Diagram.

KEY.

- I. *Fringing Forest*.—Partly evergreen. Trees, *Diospyros mespiliformis*, *Eugenia owariensis*, *Mitragyne africana*, *Celtis integrifolia*, *Anogeissus schimperi*, *Acacia campylacantha*, *A. sieberiana*, *Crataeva adansonii*, *Combretum verticellatum*, *Vitex cienkowski*, are among the more common. Creepers include *Hippocratea richardiana*, *Capparis tomentosa*, *C. corymbosa*, *Vitis quadrangularis*, *Landolphia owariensis*, *Dichrostachys platycarpa*.
- II. *River Bank*.—Thorny and other shrubs and creepers: *D. platycarpa*, *Sesbania* sp., *Salix* sp., *Fluggea microcarpa*, *Mimosa asperata*, *Ficus* sp., *Paullinia pinnata*, *H. richardiana*, reeds (*Arundo donax*) and grasses.
- III a. *River Plain, Grass*.—Grasses include *Panicum subalbidum*, *Panicum* sp., *Eragrostis* sp., with *M. asperata* and *F. microcarpa* near permanent water.
- b. *River Plain, Trees*.—"Islands" of moisture-tolerant tree-growth with *A. campylacantha*, *M. africana*, *Gardenia erubescens*, *Bauhinia reticulata*, *Ficus platyphylla*, with occasional *Pterocarpus erinaceus*, *Terminalia macroptera*.
- IV. *Backing Woodland*.—Intermediate in type between I and VII. Many large timber spp.: including *Khaya senegalensis*, *Pt. erinaceus*, *Terminalia* spp., *Combretum* var. spp., *Tamarindus indica*, *Albizzia chevalieri*, *Stereospermum kunthianum*, *Adansonia digitata*, *Lonchocarpus laxiflorus*.
- V. *Baobab & Thorn*.—A large percentage (about 45%) of the total area. A hard, dry, badly drained plain: Baobab (*Adansonia digitata*) dominant; add *T. indica*, *Balanites aegyptiaca*, *Zizyphus jujuba*, *Zizyphus mucronata*, *A. sieberiana*, *A. seyal*, *A. senegal*, *C. verticellatum*, *C. sp.*, a few *D. mespiliformis*. Grasses occasional and gregarious in slight depressions. This type usually adjoins VI.
- VI. *Marsh*.—Areas in which flooding precludes tree-growth. Possessed by grasses, principal being *Panicum pyramidalum*, *P. subalbidum*, *Eragrostis* sp. Isolated stunted tree-growth of *Mitragyne africana* and *Bauhinia reticulata* on termite mounds.
- VII. *Woodland Savannah*.—Typical of the Climatic Climax. With V constitutes nearly the whole area between the watercourses. For the most part deciduous, rich in species, among which are: *Combretum verticellatum*, *C. sp.*, *Anogeissus schimperi*, *Bombax buonopereense*, *Pseudocedraa trotschii*, *Sclerocarya birr hoea*, *Terminalia macroptera*, *Sterculia tomentosa*, *Ficus platyphylla*, *Balanites aegyptiaca*, *Prosopis juliflora*, *Entada sudanica*, *Adansonia digitata*, *Tamarindus indica*, *Stereospermum kunthianum*, *Lonchocarpus laxiflorus*, and many smaller trees and shrubs. A few *Khaya senegalensis* and *Pterocarpus erinaceus*; rare, *Paradaniellia oliveri*; and, very rare indeed, *Parkia filicoidea*.

SHERIFURI AREA



References

Footpaths.....

Dry-season Motor Roads.....

Village Headquarters.....Gatafoa

Tsetse Clearings 1925-26.....

" " 1926-27.....

" " 1927-28.....

" " 1928-29.....

which is of course purely diagrammatic, gives a representative range of species, a full botanical enumeration being beyond the scope of this paper.

The wet season is from May to September, the usual rainfall totalling about 28 inches, August being a month of floods. The cool harmattan wind blows almost continuously from December to February, and from then until the rains break the weather becomes increasingly hot and the countryside more dry.

The main plan of the experimental clearing was to eradicate the primary and the more important secondary foci of *G. morsitans* and *G. tachinoides*, beginning with the minimum possible destruction of forest which might achieve the desired result. Clearing began on a small scale in the dry season 1925-26 and was carried out at an increasing rate each season up to 1928-29. The extent of the clearing and its annual progress are shown in the accompanying map (Map 1). Up to the end of April 1929 it comprised 16½ miles of the Katagum River, the main river of the area; 20 miles of the Kiyawa River, a tributary of the former; and 42 miles of smaller streams, chiefly effluents and pools.

The fringing forest and thicket of the waterways were cut, the largest trees such as mahoganies and baobab being left untouched. Usually where a belt of good savannah backed the fringing forest, it was not cut into to any great extent, although this was done in a few localities in order to afford contrasts. As intense a fire as possible was then induced to pass through the slash; if the cutting is done early in the dry season this can be done before the onset of the rains; but if cutting is done towards the end of the dry season it is better to postpone firing until the following year. Experiments have been carried out since 1926 to determine the value of assisting fire by stacking fuel round live stumps and trees. Subsequent inspections have shown that after one or two seasons re-growth is almost normal and that this procedure produces no advantage commensurate with the extra cost. The real reason for this is that stumps when first cut are too fresh and resistant. It is much more advantageous to stack stumps after re-slashing, as they are then drier and a quantity of seasoned fuel is obtainable.

It was hoped that complete re-slashing of all re-growth for two or three successive seasons would be sufficient, but unfortunately this has not proved to be the case. There are, however, some signs of exhaustion after an area has been carefully controlled for 4 or 5 years.

Full records have been kept of the rates of re-growth in representative areas and a summary of these is given in the accompanying table. It is apparent that re-growth is very vigorous during the first year but slows down markedly during succeeding years. This loss of vigour of re-growth after the first year must be due to the exhaustion of the food reserves stored in the root system of the tree. The important point emerges that it may be uneconomical to re-slash more often than every third year.

Invasion of the clearings by creepers and grasses is an important ally. Re-growth from stumps is hindered by their matted condition; and this and the long grasses hamper the vision of tsetse. The chief creepers concerned are *Luffa aegyptiaca* (loofah), *Ipomea* spp. (convolvulus), *Smilax kraussiana*, *Lagenaria* sp., *Paullinia pinnata*, etc. The chief grasses concerned are *Pennisetum pedicellatum*, *Andropogon gyanus* and *Andropogon* sp.

Recently in an area of heavy forest less complete clearing has been tested. It consists of the removal of only dense thicket and heavy shade-bearing trees, thus constituting a heavy forest thinning. It was hoped that the areas involved would be converted into woodland savannah with good timber trees remaining. If successful, costs would be reduced, rate of work accelerated, and the locality improved by avoiding devastation. It is doubtful, however, whether such a type of clearing will be of use in *G. morsitans* country, as the wet season spread of this fly seems unaffected by it.

Experiments have been made to determine whether it is possible to utilise the inexpensive and rapid methods of ring-barking and sapping for the destruction of standing trees. By the former method a ring of bark about 18 inches wide is removed all round the tree, care being taken not to cut into the wood. In course of time, varying with species and locality, the whole tree dies. The process is slow but sure once the reserve food matter in the roots becomes exhausted. In the second method only one ring of cuts is made. These cuts enter the wood and must overlap; in making them an outward twist is given to the axe and thus a complete "frill"

Table showing Comparison of Re-growth.

Locality	Cleared	No. of years re-growth	Av. no. of shoots per tree	Av. length in feet	Chief species concerned and remarks
East of East Pond ...	1928	1	6	7.6	<i>Vitex cienkowskii</i> , <i>Anogeissus schimperi</i> , <i>Combretum verticillatum</i> and <i>Zizyphus jujuba</i>
Road Pond, west bank (experimental) ...	1929	2	6	9.1	<i>Mitragyne africana</i> , <i>Crataeva adansonii</i> , <i>Diospyros mespiliformis</i> —constituting 25% of original stocking
Road Pond, east bank (ordy. clearing) ...	1929	2	6	8.0	<i>M. africana</i> , <i>Celtis integrifolia</i> , <i>C. adansonii</i> , <i>Eugenia owariensis</i> , <i>D. mespiliformis</i> and <i>Acacia campylacantha</i> . Over 75% of original stocking still regrowing chiefly from base root suckers; due to an effective burn.
Road Pond ...	1927	3	6	9.2	<i>M. africana</i> , <i>A. schimperi</i> , <i>Tamarindus indica</i> , <i>V. cienkowskii</i> , <i>A. campylacantha</i> , <i>Z. jujuba</i>
R. Malele N. of Broad Pond ...	1927	3	11	9.0	<i>M. africana</i> , <i>C. adansonii</i> , <i>D. mespiliformis</i> , <i>V. cienkowskii</i> and <i>Dichrostachys platycarpa</i>

- Notes: (1) The averages are representative of many data available over the whole area.
 (2) The first year's re-growth, as with all coppice, is a height increment.
 (3) Height increment is maintained decreasingly over three years.
 (4) Diameter increment and crown development are negligible until the new vegetative organs have returned sufficient food material to the root system and both diameter and crown increase their rate of development after three years.

is formed. The transpiration current is completely stopped at the ring and the crown and the upper part of the bole die. The whole of the food material in the roots now forms re-growth at and below the ring from dormant buds and root-suckers. It is essential in clearings of this nature that all climbers, creepers and thicket should be dragged from the supporting trees and that fire should be induced to enter by any means available. That adopted was to connect by grass and slash the clearing with the adjacent grass ecotone. Sapping results in a condition similar to ordinary coppice re-growth and this must subsequently be re-slashed, as is done after felling.

The final results from both methods have proved to be irregular and in some areas unsatisfactory, the partial failure being due apparently to the axemen's lack of skill. Ring-barking evidently is unsuitable under existing conditions, as it requires

too much care in execution. Sapping is simpler, quicker and less expensive, but like the former method its results are uneven and not sufficiently rapid in effect to be of use in the type of clearing at present undertaken by the Tsetse Investigation. It is worth noting that a tree little affected by either of the above methods owing to the deeply creviced nature of its trunks, the Giyea (*Mitragyne africana*), is prevalent in *G. tachinoides* areas in the Northern Provinces of this country. Nothing short of actual felling has proved effective in the case of this tree.

It has been found experimentally, as already indicated, that it is of the greatest value to burn all possible stumps in re-slashing. After this treatment the re-growth is very feeble. In some favourable localities up to 30 per cent. of all stumps were killed by a burn which penetrated deep into the roots and left large cavities in the soil. The cost of this type of work is about 25 per cent. greater than for ordinary re-slashing, and when the labour becomes more experienced this figure probably could be reduced considerably. For this kind of work it is essential that grass burning ahead of the re-slashing should be prevented.

The Hausa and Kanuri population in the Northern Provinces is almost entirely agricultural, and it follows that large-scale clearing experiments involving areas of heavy fringing forest and dense thorn thicket, which constitute the primary foci of *G. tachinoides* and *G. morsitans*, can only be undertaken in the dry season months between the reaping of one season's crops and the sowing of the next. In practice this means that clearing labour can only be obtained from November until April. In the early days of the Tsetse Investigation there used to be considerable difficulty in obtaining labour even in the dry season, but as the natives became accustomed to the work, it was increasingly popular and the supply of labour exceeded the demand. Ordinary labourers' wages had to be paid.

It has been found after experiment that the most effective tools for this type of work are the short-handled hawk-eye axe and the stout matchet. For clearing heavy masses of the thorny creeper, Sarkakiya (*Dicrostachys platycarpa*), a long-handled secateur has been found most useful, particularly where, as in many places, the Sarkakiya hangs in masses from the branches of trees, thus preventing the labourers getting at the trunk for felling.

The most efficient clearing unit has been found to be a gang of about 100 labourers with one fully trained and one or two semi-trained headmen. It has been necessary to maintain a considerable degree of European supervision, but this is becoming less essential as the headmen attain greater proficiency and reliability.

3. The Effect of Clearing on Tsetse in the Sherifuri Area.

Certain of the foci have been studied closely for 6 years and the figures accumulated in respect of several of them are recorded in an Appendix. A full description of the routine followed and of the primary and secondary foci studied has already been given³ and the following notes point out how the field experiments affect the various factors.

Female Percentages in Catch.

With *G. morsitans*, both after clearing and after exclusion of game by the fence, the proportion of females in a catch was greater than before, but during the rains this increase was less marked. The reason for the increase is the disturbance caused in the fly's food supply. The sex proportion was not influenced by the experiments in the case of *G. tachinoides*.

Rate of Catching (Flies per Boy-hour).

The Eastern Pond (Tables I and V). Here the heavy savannah backing the fringing forest was left standing when the latter was cut. It continued to harbour *G. morsitans* during the rains with a maximum density in October, though the fly

became relatively scarce in the dry season proper. This invasion decreased almost in proportion as the clearings were extended through the neighbouring primary foci up to a distance of about four miles from the point of collection. Clearing up to 800 yards from the collecting centre had no apparent effect on the wet season extension, but at four miles it was reduced to about one-sixth of the old figure. This important point is illustrated in the following table:—

Year	Distance to nearest uncleared primary focus	Density in October	
		<i>G. morsitans</i>	<i>G. tachinoides</i>
1925	No clearing	62	103
1926	300 yards	64	25
1927	800 "	82	2
1928	2,500 "	13	7
1929	7,000 "	10	scanty

Note.—The October distribution of *G. tachinoides* and *morsitans* is more even in primary and secondary foci than at any other time of the year.

With *G. tachinoides*, when the clearing extended 300 yards from the collecting point, there was a marked reduction in density and from 800 yards and over this fly spread little along the clearings, and in October 1929 was not seen there apart from rare stragglers.

River Pond (Tables IV and VII). This primary focus, approached by a different path from the camp, is really a continuation of the last one, and about a mile from it, there being no break originally in the forest between them. To obtain a contrast in treatment the backing savannah was cut down as well as the fringing forest, and a piece of this was farmed in 1928. The reduction of *G. tachinoides* was much as at the former locality, but that of *G. morsitans* was more marked, the savannah woodland having gone. This fly became very scarce indeed, dropping from nearly 200 per boy-hour in August–September 1927 to almost complete absence in 1928 at the same season. In addition to the absence of shade the farming helped in this result, as it kept the game at a distance during daylight.

Village and Round Ponds (Table III). These were secondary foci, the pools drying completely about February. A patch of heavy savannah was left near the Round Pond, but that near the Village Pond was cut down as it straddled the main road. This piece was farmed and thereafter *G. morsitans* was very rarely seen in it. The uncleared piece of savannah was of interest, as in September and October 1927, when the neighbouring primary foci were being cleared, there was a definite concentration here. Densities of 129 and 78 respectively were obtained, figures which were unprecedented there. As at the Eastern Pond, it was not until the clearings of the primary foci had been pushed back about four miles that *G. morsitans* became scarce at this collecting point during the wet season spread; even so it held a density of 18 in October 1929. *G. tachinoides* was scarce after the clearing of the fringing thicket, only stragglers being found.

Road Pond (Tables II and VI). This was not cleared till 1929 but was fenced round in 1925, game being thus excluded from the pool and the surrounding half square mile of country. The history of the experiment up to May 1926 has already been given,³ and subsequent observation has served to confirm the conclusions

which were drawn, with the exception that we then had an exaggerated idea of the adverse effects of the game exclusion on *G. tachinoides*. In most respects the colony of this fly at the pool has been normal since 1926. In the case of *G. morsitans*, after the enclosure was made it became evident that the flies caught were only invaders which came from neighbouring foci and were starving inside the fence. Through this one obtains some idea of the distance to which *G. morsitans* spreads, the October concentrations being as follows:—

Year	Distance to nearest uncleared primary focus	October <i>morsitans</i> density in fenced area, not cleared
1925	300 yards	21
1926	860 "	15
1927	2,500 "	16
1928	3,000 "	9

These densities may be contrasted with those of the Village Pond and Round Pond, the control area, in which the October density of *G. morsitans* was normally from 35–60.

The fence was removed at the end of 1928 and in 1929 the fringing thicket of the pool was cleared but the backing savannah was hardly disturbed and the place was much in the condition of the Round Pond (see above). In October 1929, with other foci about 3 miles away the density of *G. morsitans* was represented by the nominal figure of 1 and that of *tachinoides* by 4, the latter fly still sheltering in small numbers under trees which had been sapped but had as yet been little affected thereby.

State of Nutrition.

That clearing the fringing forest induces a state of starvation in the *G. morsitans* which are still to be found in neighbouring savannah is very evident from Table I; the same effect, but more enhanced, being shown in Table II as a result of game exclusion. With *G. tachinoides* the effect is less marked, as this fly becomes scarce after clearing, without showing first any particular hunger. The exclusion of game, however, produced a certain amount of starvation in them, as Table VI shows.

Proportion of Soft Flies.

The proportion of young soft flies in the catch is of course ordinarily indicative of the rate of breeding. With *G. morsitans* the proportion of these rises considerably after clearing, as it did at the Road Pond in certain seasons after the fencing. The first sudden rise at clearing is due to flies emerging from the pupae which remain in the ground after most of the active flies have disappeared. The later effect is probably due to the fact that recently emerged *G. morsitans* are more liable to wander than the older flies. This we deduced from the conditions in the fenced area, where in the dry season the proportion of young flies was out of all reasonable proportion to the flies which completed the catches, so many of these being starving; e.g., during 1926–28 from October to May an average of 36% of the flies were starving and a further 20% had recently emerged from the pupae (see Table II). If invasion by young flies is discounted, this would mean a rate of reproduction of about one a day by the females instead of the highest possible rate of about one in ten days. The abdomens of the females examined were nearly all wafer-like, and it was certain they were not in a breeding condition.

Recognisable Blood in the Flies.

It has been shown that the proportion of starving flies may be high, and yet the proportion containing recognisable blood be about normal. This was a characteristic of *G. morsitans* in the fenced area and was due to flies being brought to the neighbourhood on animals and then passing into the fence where game was absent. In the clearings also the proportion of flies containing blood was about normal though there was evidence of starvation and the same reason accounts for it; for the game, though visiting the clearings, lingered in the areas less than formerly.

With *G. tachinoides*, though the proportion of flies containing recognisable blood was about as before, the amount taken from non-mammalian sources was increased inside the fence and in general also at the Eastern Pond after clearing. This is understandable, as the thicket-haunting mammals are driven to the savannah by the clearings, but the amphibious reptiles must remain close to the water or go right away from the area affected.

Rate of Infection.

There is no evidence that the rate of trypanosome infection was influenced in any regular manner by the clearings. At first it appeared to be slightly reduced inside the fence with *G. tachinoides* but not with *morsitans*. The final figures obtained

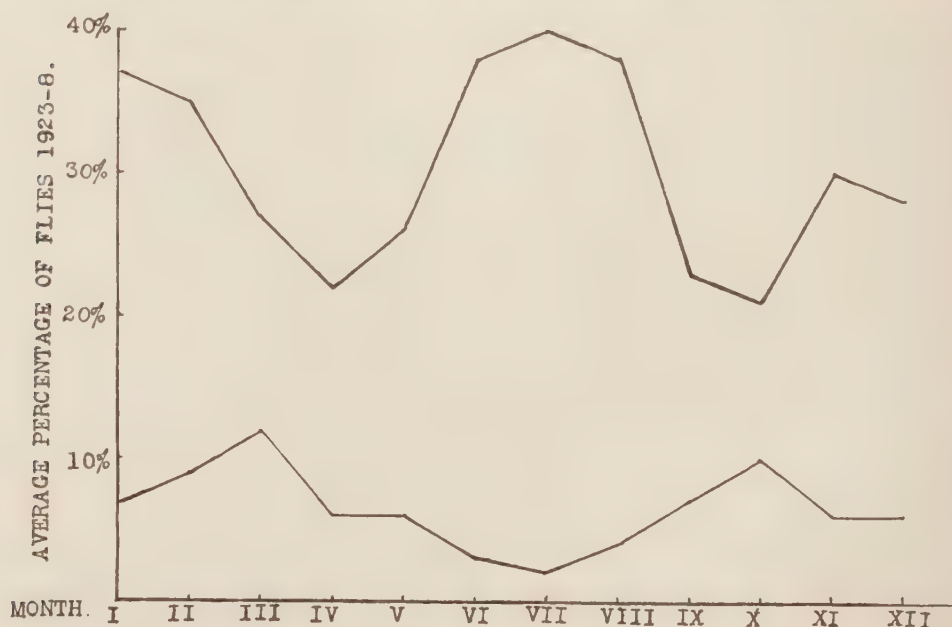
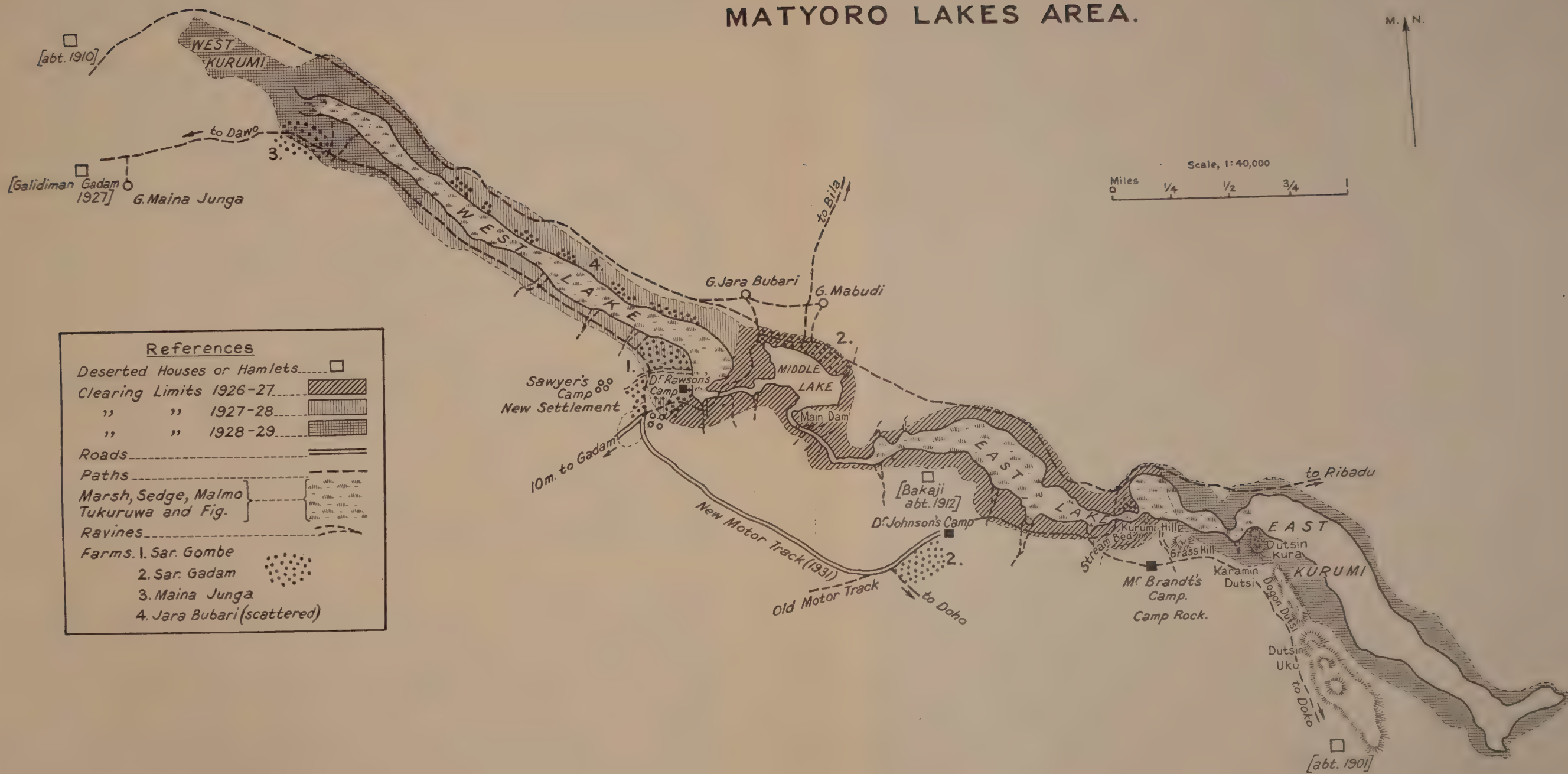


Fig. 2. Showing the relationship in *G. morsitans* between rate of infection with *T. congolense* and *T. vivax* (upper curve) and proportion of young flies (lower curve). The curve is based on the examination of about 10,000 flies.

are: *G. morsitans*, before fencing 2,791 flies examined, 19.2% infective with *Trypanosoma vivax* and 3.5% with *T. congolense*; after fencing 4,763 flies, 17.0% infective with *T. vivax* and 3.5% with *T. congolense*. *G. tachinoides*, before fencing 4,183 flies, 5.0% were infective with *T. vivax* and 1.3% with *T. congolense*; after fencing 4,762 flies 4.8% were infective with *T. vivax* and 1.2% with *T. congolense*. The figures for the two periods are thus almost exactly the same, and this is curious,

MATYORO LAKES AREA.



because the factor which most influences the rate of infection in *G. morsitans* is the average age of the flies, and it has been mentioned that young flies were in excess of normal after the fence was closed.* In *G. tachinoides* the variation in diet is the factor which mostly influences the trypanosome infection rate. Where reptile blood bulks largely in the food of the fly, trypanosome infection is low (i.e., *T. vivax* and *T. congolense*, not including *T. grayi*), and when antelope blood is more prevalent the infection rate is higher. At the same time variation in proportion with the average age of the flies can be seen for this species also. The accompanying chart gives the average seasonal total infection in *G. morsitans* over six years at the Eastern Pond and contrasts it with a similar average of the proportion of soft flies and illustrates well this relationship between average age, or rate of breeding, and infection.

4. The Matyoro Area.

The Matyoro area (Map 2) forms the second of the experimental clearing areas. It consists of a chain of swamps and open lakes lying in a depression of roughly 150 square miles, situated some 20 miles north-west of Gombe town and connecting with the Gongola River. The system of swamps and lakes constitutes the only surface water for many miles, the country being dry and sandy with rocky outcrops and covered with a thin deciduous forest. The system, through which water flows throughout the year, lies in a shallow valley which narrows down in one place to form a gorge. From east to west the formation is red sandstone, conglomerate, ironstone. The depth of the water has increased in relatively recent times as shown by dead *Eugenia owariensis* and *Diospyros mespiliformis* trees in the middle (and deepest) lake. The vegetation of the whole area is an interesting edaphic climax and presents a remarkable contrast to the semi-arid type of the locality. It is subtropical, evergreen and includes the following species, all typical of more southern lands with a far heavier rainfall than this arid locality experiences: *Chlorophora excelsa*, *Khaya grandis*, *Albizia brownei*, *Pterocarpus* sp., *Eugenia owariensis*, *Pandanus utile*, *Elais guineënsis*, and *Raphia vinifera*, together with species which are also met with in the Sherifuri area such as *Khaya senegalensis*, *D. mespiliformis*, *V. cienkowskii*, *A. campylacantha*, *T. indica*, etc. The lianes are many and of a corresponding type.

Backing the sub-tropical forest, and on the well drained slopes of the valley, is a woodland savannah of good quality. Essentially a *Combretum* association, it contains as dominants *Anogeissus schimperi*, *Combretum verticellatum*, *Combretum* spp., and *Terminalia macroptera*; less frequent, *Khaya senegalensis*, *Azelia africana*, and *Tamarindus indica*; frequent but local, *Adansonia digitata*, *Bulbosperrum parkii*, and occasional *Isobertinia doka*.

The problem here is an entirely different one from that at Sherifuri, the vegetation being more tropical and the foci more concentrated. *Glossina morsitans*, *G. tachinoides* and *G. palpalis* all occur in the area. In the wet season *G. morsitans* ranges widely from the heavy forest, but in the dry season this species is concentrated in the primary foci formed by the evergreen forest and the heavy forest immediately bordering this. The other two species are confined to the fringing forest of the lakes, swamps and streams in the area. Game is abundant and forms the principal food supply for *G. morsitans* and *G. tachinoides*. *G. palpalis* (and *G. tachinoides* to a smaller extent) obtains a part of its food supply from crocodiles and monitor lizards, both of which are numerous in the lakes. Baboons are very numerous, large troops frequenting the fringing forest, and it was shown by Johnson & Rawson⁴ that both *G. morsitans* and *G. tachinoides* were feeding on these animals to a considerable extent.

* M. Robertson (Rep. S. S. Comm. Roy. Soc., xiii, 1913) found that if *G. palpalis* were starved up to a point after they had acquired *T. gambiense* the chances of the infections maturing were thereby increased. This effect may be responsible for the apparent anomaly.

The Matyoro area was completely uninhabited, the natives of the neighbouring districts regarding the place with superstitious fear and having many quaint stories and legends to account for their avoidance of it. Many of these tales were calculated to inspire fear and were doubtless propagated by the hunters who frequented the place. These were actively opposed to the clearing and made themselves a nuisance. The only evidence of human occupation, previous to the last two decades, is the remains of a stone-built pagan village, the history of which could not be obtained. Since 1910, however, several small settlements were formed but were deserted admittedly on account of sleeping sickness, or as the natives expressed it "Because the air was bad and they died." The abundance of the two species of riverine tsetse would almost certainly have prevented considerable settlement or sustained occupation. A settlement has now been formed, and it is hoped that this will develop on a scale sufficient to colonise all the available cleared land.

Apart from the riverine tsetse, *G. morsitans* has been so numerous that the unfailing supply of surface water and the potential grazing it affords have been rendered inaccessible to the large herds of cattle in the surrounding country. They have to be watered from deep wells and sustained on poor grazing, or have to trek long distances in search of water and grazing. In the important town of Gombe, some twenty miles away, water may be so scarce during the dry season that the supply has to be controlled by native policemen.

In order to open up the Matyoro area for settlement and to make its water supply and grazing accessible to cattle, clearing was begun in the dry season of 1926-27. During this and the following two seasons six and a half miles of the valley were cleared, including the fringing forest and the adjacent heavy woodland savannah. During the later part of this work all good timber trees were spared, and these are now providing timber on a large scale for the Native Administration.

Above the present cleared area the valley is dry for some miles, while below it the forest continues the same dense sub-tropical type along the watercourse to the south and east. In the cleared area in January 1929 no *G. palpalis* or *G. morsitans* could be found, and *G. tachinoides* was very scanty. In July 1929 groups of settlers were farming in the clearing, and only straggling tsetse were found till the edges of the clearings were approached. Fear of the place still persisted, and no cattle or horses were being kept in the area. During the wet season of 1930 two cows from Gombe and a horse belonging to a settler were brought in and all remained in good health. The number of settlers is increasing, and it is to be hoped that cattle-owners will take advantage of this excellent dry season water and grazing, which should be quite safe provided that the eastern and western extremities of the clearing are avoided. It is unfortunate that baboons have been responsible for a certain amount of damage to the crops of settlers. The remedy appears to be more compact farms and more careful supervision by the farmers.

The problem of re-growth in the hygrophilous vegetation is much more difficult than in the type of forest in the Sherituri area. The two trees giving most trouble are the aquatic fig and the tukuruwa palm (*R. vinifera*). The former has a great capacity for regeneration, not only from its old stem but also from the twigs which break off when the tree falls on cutting into the water. A shoot with roots was even found growing from a chip of bark cut by an axe in the previous year. There are now enormous numbers of these young figs in the swamps, and they will be very difficult to control. The tukuruwa palm also makes rapid re-growth, and it was noted that where it had been slashed back twice it made a greater number of shoots, though these were less vigorous. The essentials for its control are thorough re-slashing with a fire as late as possible in the year. Much stacking of the slash was done in the first season's clearing, but the results did not justify the extra labour involved.

It was noted that re-growth in general was much less vigorous in those parts of the swamp where the water was deeper, than in the shallower parts. It seemed likely that if the swamps could be deepened by even a few feet, a retarding effect would be obtained. A dam of timber and rough stone was constructed in the narrowest part of the gorge in the middle of the valley in the dry season 1928-29. This dam was 30 feet long, 12 feet wide at the top and about 20 feet wide at the base, its height being 10 feet at the face and 8 feet at the back. At the same time a shallower dam was made in another part where the stream narrowed. During the following wet season the latter was breached by water which passed the main dam, and the first attempt at damming was thus a comparative failure, as no great depth of water could have been held back. During the following dry season a more substantial dam was constructed, and this was successful in raising the level of the lakes above it some three or four feet.

Recent inspections have shown that above the dam there is a distinct measure of ill-health of the *Raphia* palm which was effected by the flooding. There is increase of *Cyperus* sp. (sedge) and *Nymphaea* sp. amounting to a slight invasion, and some increase of *Ottelia cancellata* and *Caldesia pinnatifolia*, with grasses such as *Fuirena umbellata* and *Cynodon* sp. at the edges. Immediately below the dam the fig has suffered most, water being less abundant than formerly, and in the driest part there is a small but very striking invasion by *Polygonum lanigerum* with grasses such as *Panicum pedicellatum* and *Andropogon*. Further, where moisture is more abundant a vigorous intruder is *Pteris* sp. (bracken). Other invasion, chiefly in the western forest, is mainly of the grass and herb type noted in the Sherifuri area, but is more vigorous owing to the change brought about by exposure of the soil and loss of moisture. It is possible that continued flooding would have a cumulative effect, and it is likely that valuable invasion and succession will continue to develop where moisture has been reduced.

5. Protective Clearings.

Apart from the large experimental clearings mentioned, the Tsetse Investigation has carried out anti-tsetse clearings in Kano, Zaria, Bauchi, Plateau and Benue Provinces. These clearings vary from small block clearings to protect roads crossing tsetse-infested streams, to others involving the clearing of primary and secondary tsetse foci over a considerable area, such as was done at Rano in Kano Province. Here the desertion, through sleeping sickness, of the important town of Rano and of many villages in the surrounding country has been prevented, and *G. tachinoides* exterminated in the district. By the application of methods and principles acquired in the experimental areas the cost of such clearings has been reduced greatly and their efficiency increased. Their aim is stabilisation by farming of an open biotic climax vegetation; but periodic inspection by Tsetse Investigation officers will be needed on account of the general shifting nature of the cultivation. It is hoped that as the value of these protective clearings becomes apparent the original cost of some such clearings, and the upkeep of all, will be borne by the Native Administration of the district concerned.

6. Late Grass Burning.

The objections to postponement of grass burning in Northern Nigeria have been fully dealt with before.³ Briefly, they arise firstly from the natives themselves, to whose interest it is to burn the grass early. Nomad graziers, charcoal-burners, honey-collectors and hunters, are to blame for much of the early burning, and it is difficult to protect a large area from their attentions. The second and more fundamental reason which prevents successful grass burning over a wide area is that the type of country in Northern Nigeria does not lend itself to sweeping fires on a large scale. Though considerable stretches of long grass occur, and may burn very fiercely, they are interspersed with stretches of low-lying ground, usually flooded in the rains,

and bearing a low fluffy type of grass, Roba (*Panicum pyramidale*), which burns slowly and feebly. Moreover, massive thicket growth, such as is very common in patches both in open country and particularly on the edge of fringing forest, is rarely affected by grass fires, or merely has its outer surface scorched. Such unburnt patches form perfect shelter for tsetse driven by the fires. In the dry season of 1927-28, an experiment was carried out in which it was attempted to burn out established thicket by stacking grass in and around the thicket edge and firing it in the late dry season, a method of control which Swynnerton⁵ found possible in Tanganyika Territory. The thicket chosen varied from a few feet to 20 yards in width, and its edge was stacked with grass for its whole length of one mile along both sides of a pool. It was fired late in January with a strong wind blowing obliquely along the thicket. The fire was fierce but failed to penetrate the thicket to any considerable depth. In the following dry season it was evident that the fire had had no appreciable effect in reducing the thicket.

At the time of the burning the density of *G. tachinoides* was 38 per boy-hour. The day after the fire it was 14 per boy-hour and six days later 12 flies per boy-hour. The day before the fire 154 flies were caught and released again after being marked with a spot of paint on the thorax. The day after the fire 13 (8.4%) of these were re-caught at the pool and in all 24% of those marked were recaptured there in the following six weeks. Subsequent experiments in marking large numbers of the fly and re-catching the day after marking have shown that about 16% of the marked flies are recaptured on that day. It appeared then that the fire had destroyed or driven right away about one-half of the tsetse infesting this focus. In the following wet season the focus was thoroughly repopulated, the density in October being 53 flies per boy-hour, as against a maximum density of 48 per boy-hour in the previous year.

A method of burning out thicket which gave much better results was tried at Matyoro. The aim was to obtain a steady and continued fire rather than a fierce brief one. The thicket, chiefly *Dichrostachys platycarpa*, was stacked with grass and any wood fuel available. In addition it was packed below well into the thicket and the whole fired simultaneously. The crown fire was fierce and rapid and then fell and joined the ground fire. The whole continued to burn for more than 48 hours and caused intense soil heat. Inspected twelve months later, dead and charred roots could be pulled out by hand and there was no re-growth. After 18 months the situation was practically the same except that there were a few weak shoots of re-growth, but the site enriched by wood ash was vigorously invaded by grasses and herbaceous creepers.

Between the dry season of 1924-25 and the dry season 1928-29, four main experiments on the effect of late grass burning on *G. morsitans* and *G. tachinoides* were carried out in the Sherifuri area. Two of these have been described already.³ The remaining two provided further evidence that a considerable mortality in fly and pupae of both species resulted from late burning, though this reduction was masked very soon by invasion from outside areas.

It is not proposed to carry out any further experiments in fire protection and late grass burning in Nigeria as four years' experience has shown that under local conditions the results obtained do not justify the expense and difficulties which fire protection involves.

7. Summary.

1. This report continues the account of the experimental field work carried out by the Tsetse Investigation in Northern Nigeria from May 1926 up to the end of 1929. *G. morsitans* and *G. tachinoides* are the tsetse concerned. The main object

of this work was to attempt to control tsetse by the destruction of primary and secondary foci by the clearing of all fringing forest, the general woodland being left untouched. Two main experimental areas have been dealt with, the Sherifuri area described previously and the Matyoro experimental area.

2. Methods of clearing and dealing with re-growth are described in detail. Records show that re-growth although very rapid the first year, then slows down to such an extent that it may not be economical to re-slash more often than every third year. The effect of clearing on tsetse was controlled by collecting fly week by week from certain fixed foci. These flies were dissected and the following factors noted: the sex proportion in the catch, the rate of catching, the state of nutrition, the proportion of very young flies, the blood content of the gut with classification of the kinds of blood found, and the trypanosome infection.

With *G. morsitans*, clearing of fringing forest only up to 800 yards from the collecting centre had no apparent effect on the wet season extension but at four miles it was reduced to one-sixth of its old figure. With *G. tachinoides* on the other hand there was a marked reduction of density when the clearing extended 300 yards from the collecting centre, and from 800 yards and over the spread was practically nil. When the backing savannah was cut down in addition to the fringing forest, the reduction of *G. morsitans* was very much more marked.

Observations on the fenced area confirm previous conclusions, with the exception that we had then an exaggerated idea of the adverse effects of game exclusion on *G. tachinoides*. In most respects the colony of this fly remained normal until the focus was cleared, while in the case of *G. morsitans* the flies caught were only invaders from neighbouring foci.

3. The Matyoro experimental area is described in detail. This consists of a chain of swamps and lakes which constitutes the only permanent surface water for many miles, the surrounding country being dry and sandy and covered with a thin deciduous forest. *G. morsitans*, *G. tachinoides* and *G. palpalis* were all prevalent, and the area was completely uninhabited.

In order to open up the district for settlement and to make its water supply and grazing accessible to cattle, six and a half miles of the valley have been cleared, the fringing forest and its adjacent heavy woodland savannah both being cut. Groups of settlers have since come in and it is hoped that in time these will be sufficiently numerous to colonise all the available land.

4. Localised protective clearings have been carried out in various parts of the country. These vary in size from small block clearings to others of a considerable area; their cost has been reduced and their efficiency increased by the application of methods acquired in the experimental areas.

5. Further experiments in deferred grass burning were carried out, and these afford additional evidence that late burning results in a considerable mortality of fly and pupae of both species. The reduction in fly is masked very soon by invasion from outside areas, and the net results do not justify the expense and difficulties which fire protection involves in this country.

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APPENDIX.

NOTES ON TABLES I–VII.

The original intention was to examine at least 200 flies from each locality each month but this number could not always be obtained on the allotted days. Percentages based on 50–100 flies are marked with one asterisk and those based on less than 50 are marked with two asterisks.

The continuous lines which subdivide the tables indicate the time when conditions were changed by experimental clearing or fencing.

An "s" indicates that the flies were present but very scanty, *i.e.*, less than one fly was captured to the boy-hour.

Figures in heavy type indicate the culminating points in rises of various factors under normal conditions.

TABLE I.

The results of the examination of *G. morsitans* at the Eastern Pond (a primary-focus). The thicket on its bank was cut in March–April 1926 and re-slashed in 1928 and 1931; the neighbouring heavy savannah was left uncut.

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(a) Female percentage	1923	7	13	7	6	4	9	5	11	16	23	16	9
	4	11	11	7	9	7	5	7	11	24	22	14	13
	5	10	7	2	7	5	4	5	6	—	13	10	4
	6	5	3	5	15	5	2*	9	13**	23	11	7	16
	7	22	22	11	6	13	11	11	25	29	18	22	9
	8	10	21	33	10*	5*	6*	21*	27	30	35*	18*	17
(b) Rate of catching	9	8*	2	12	6	10	—	—	—	—	16	—	—
	1925	—	—	100	101	119	100	100	49	—	62	97	71
	6	72	106	47	35	15	11	26	43	61	64	36	23
	7	9	13	14	17	6	9	13	44	78	82	43	27
	8	14	12	13	4	2	5	5	9	15	13	12	8
(c) State of nutrition: percentage of starving flies	9	9	14	8	8	7	—	—	—	—	10	—	—
	1924	—	—	—	—	—	—	—	8	9	6	1	2
	5	0	0	0	1	5	8	15	16	—	5	4	7
	6	1	4	20	31	32	7	7	18	15	14	7	4
	7	30	36	31	12	23	28	37	21	43	35	22	25
(d) Young flies: percentage of soft flies	8	25	33	34	21**	10**	6*	21*	19	26	35*	40*	—
	1923	—	—	—	—	—	—	—	—	—	—	0	1
	4	8	8	4	2	4	2	2	2	2	1	3	2
	5	2	3	1	1	2	1	2	3	—	7	10	9
	6	3	1	13	27	16	5*	2	5*	11	7	3	13
	7	17	20	20	10	20	10	4	11	9	7	5	7
(e) Recognisable blood in flies: percentage	8	6	15	21	0**	0**	0*	0*	1	7	21*	13*	—
	9	—	—	—	—	—	—	—	—	—	0*	—	—
	1923	—	—	—	—	5	5	14	14	14	19	29	25
	4	26	20	22	16	22	17	24	21	15	17	26	28
	5	35	13	34	36	15	10	17	17	—	22	22	22
	6	12	13	9	10	13	25*	25	7*	6	13	21	18
	7	19	16	15	23	18	29	15	22	20	11	34	24
	8	15	8	12	3**	16**	22*	19*	16	13	18*	35*	—

TABLE I—(Continued).

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(f) Rate of infection percentage	1923	58	43	32	25	27	39	35	29	19	13	31	36
	4	35	26	37	31	33	35	46	35	26	21	13	14
	5	45	47	45	38	25	35	41	48	—	31	35	34
	6	28	41	18	/ 10	23	45*	50	50*	26	26	32	31
	7	22	23	16	6	9	41	31	30	26	17	31	23
	8	33	32	14	21**	42**	34*	35*	38	16	16	39	—

The distance to the nearest primary focus was :—1923–1925, continuous in both directions ; 1926, 300 yards ; 1927, 800 yards ; 1928, 2,500 yards ; 1929, 7,000 yards.

TABLE II.

The results of the examination of *G. morsitans* at the Road Pond (a secondary focus). The pool was fenced round and the game excluded in February 1925.

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(a) Female percentage	1924	—	—	16	16	28	10	18	13	14	19	12	5
	5	26	/ 25	26	30	18	4	6	15	—	23	33	17
	6	23	25	23	30	19	12**	28**	22*	20	19	24	29
	7	39	18	27	33*	26*	13*	20**	23**	52	23*	19**	21*
	8	35**	45*	42*	81**	5	0/4	45**	32**	45	36*	41**	—
(b) Rate of catching	1925	—	/	15	18	6	4	8	9	—	21	28	20
	6	19	24	25	23	8	3	4	5	14	15	18	5
	7	4	12	14	6	3	3	2	5	14	16	10	3
	8	2	7	5	2	2	2	1	2	7	9	3	—
	9	—	2	—	4	—	—	—	—	—	1	—	—
(c) State of nutrition: percentage of starving flies	1924	—	—	—	—	—	—	—	4	7	1	3	1
	5	0	/ 1	12	32*	18	12	16	22	—	28	13	31
	6	39	32	41	25	46*	13**	20**	31*	38	20	18	25
	7	51*	39	49	29*	21**	29*	56**	68**	58	61*	40	30*
	8	31*	38*	46*	50**	10**	0/4	36**	43**	47	47*	47*	—
(d) Young flies : percentage of soft flies	1924	—	14*	10	6	30	3	1	2	1	1	2	1
	5	6	/ 13	17	13	4*	2	4	5	—	11	15	15
	6	26	27	25	45	25*	0**	16**	6	10	9	13	19
	7	25*	26	12	27*	21**	6*	4**	7**	11	6*	10	22*
	8	0**	31*	34*	31**	0**	1/4	0**	5**	1	16*	3**	—
(e) Recognisable blood in flies : percentage	1924	—	16*	16	13	15	16	16	16	14	15	17	9
	5	14	/ 12	24	21	25*	15	11	15	—	12	12	13
	6	10	14	9	9	1*	13**	20**	10*	9	13	9	11
	7	7*	10	14	10*	26**	29*	8**	10**	19	11	16	18
	8	14**	9*	12*	19**	16**	0/4	0**	5**	14	38*	30**	—
(f) Rate of infection: percentage	1924	—	13*	25	12	9	51	55	39	21	31	23	29
	5	22	/ 25	23	18	18*	38	37	34	—	24	32	31
	6	19	32	26	9	18*	75**	56**	47*	25	35	31	14
	7	26*	18	14	9*	5**	28*	52**	51*	52	23	30	22
	8	28**	16*	18*	6**	42**	3/4	45**	40**	35	28*	41*	—

The data in Table III form a control to the above up to May 1927.

The distance to the nearest primary focus was :—1924, almost continuous ; 1925, 300 yards ; 1926, 860 yards ; 1927, 2,500 yards ; 1928, 3,000 yards ; 1929, 5,000 yards.

TABLE III.

The results of the examination of *G. morsitans* at the Village and Round Ponds (a secondary focus). The fringing thicket was cut in three sections at intervals in 1926–27 ; neighbouring heavy savannah was left uncut.

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(a) Female percentage	1923	14	13	18	6	10	10	10	11	10	18	14	7
	4	14	12	16	16	22	17	26	24	10	18	13	10
	5	12	17	7	20	16	21	27	14	—	15	12	15
	6	9	7	10	14	10*	12	12	48	25	18	10	13
	7	26	10	9*	20*	—	—	21	22	38	29	16	14
	8	—	—	—	—	—	—	—	—	16	23*	12	8
	9	0**	—	20**	63**	—	—	—	—	—	20*	—	—

TABLE III—(Continued).

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(b) Rate of catching	1925	—	—	41	28	25	5	12	31	—	62	45	42
	6	39	44	56	12	8	11	17	29	47	35	40	33
	7	14	13	11	3	1	s	12	46	129	78	25	15
	8	—	—	—	—	—	—	—	—	23	41	18	21
	9	6	16	3	1	—	—	—	—	—	18	—	—
(c) State of nutrition: percentage of starving flies	1924	—	—	—	—	—	—	—	7	3	7	5	3
	5	0	0	6	9	10	11	12	24	—	14	16	22
	6	7	5	4	8	14*	9*	17	14	34	21	7	5
	7	7	8	2	2*	—	—	36	32	48	30	23	33
	8	—	—	—	—	—	—	—	—	18	20**	19	—
(d) Young flies : percentage of soft flies	1923	—	—	—	—	—	—	—	—	—	—	1	4
	4	12	11	11	12	12	1	2	1	0	2	4	3
	5	4	7	6	16	25	3	2	5	—	8	5	18
	6	7	3	10	19	10*	3*	4	2	16	10	3	14
	7	13	11	8	24*	—	—	27	13	13	5	7	12
(e) Recognisable blood in flies : percentage	1923	—	—	—	—	24	16	15	16	19	22	22	26
	4	18	20	12	17	32	26	28	21	16	17	14	16
	5	14	15	25	21	17	11	20	20	—	15	16	17
	6	7	13	22	15	19*	25*	17	23	5	27	27	20
	7	21	17	25	26*	—	—	16	17	13	23	15	18
(f) Rate of infection : percentage	1923	14	16	20	12*	31	58	43	36	23	15	16	22
	4	24	19	14	14	10	50	52	35	27	22	15	31
	5	28	15	16	9	7	43	47	43	—	19	31	35
	6	34	20	11	6	18*	49*	47	48	24	28	39	26
	7	26	18	21	22*	—	—	19	32	25	35	16	47
	8	—	—	—	—	—	—	—	—	22	32**	34	—

The distance to the nearest primary focus was :—1923–1927, almost continuous ; 1928, 4,000 yards ; 1929, 7,000 yards.

TABLE IV.

The results of the examination of *G. morsitans* at the River Pond (a primary focus). The fringing thicket and the backing savannah was cleared in Nov.–Dec. 1927. Part was farmed May–Oct. 1928.

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(a) Female percentage	1926	—	—	—	—	7	4	8	9	16	17	38	12
	7	5	3	3	9	1	1	5	7	28	16	7	8
	8	6	14	10*	8	7*	—	—	—	0/2	—	—	—
(b) Rate of catching	1926	—	—	—	—	33	61	83	125	89	100	61	46
	7	65	65	127	127	126	139	123	190	167	55	55	24
	8	13	16	14	15	18	17	s	s	s	1	—	—
(c) State of nutrition: percentage of starving flies	1926	—	—	—	—	9	13	23	19	21	23	5	4
	7	2	2	3	1	4	5	16	12	15	31	23	18
	8	17	12	24*	8*	19	4*	—	—	—	—	—	—
(d) Young flies : percentage of soft flies	1926	—	—	—	—	9	3	3	8	8	8	0	11
	7	3	2	4	3	8	2	1	1	3	4	1	10
	8	6	7	19*	3*	4	0*	—	—	—	—	—	—
(e) Recognisable blood in flies : percentage	1926	—	—	—	—	32	14	5	3	8	14	21	25
	7	22	29	17	19	26	32	21	16	38	22	21	—
	8	29	18	14*	20*	16	14*	—	—	—	—	—	—
(f) Rate of infection: percentage	1926	—	—	—	—	23	35	43	27	15	17	38	45
	7	43	33	37	25	15	41	49	42	43	34	32	40
	8	52	48*	22*	30*	33	6*	—	—	—	—	—	—

The distance to the nearest primary focus was :—1926–27, continuous ; 1928, 3,000 yards ; 1929, 8,000 yards.

TABLE V.

The results of the examination of *G. tachinoides* at the Eastern Pond (a primary focus). The fringing thicket on its bank was cut down in March-April 1926.

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(a) Female percentage	1923	46	16	30	51	42	39	33	35	34	40	41	38
	4	39	27	30	49	47	40	36	37	34	39	36	40
	5	32	33	30	27	47	27	18	34	—	41	38	36
	6	26	27	32	42	40	27	38	45**	63	47	23	30**
	7	36	19*	70**	—	—	—	—	—	—	—	—	—
	8	—	—	—	25**	—	—	—	—	—	54*	—	—
(b) Rate of catching	1925	—	—	—	—	—	100	100	56	—	103	98	50
	6	46	69	48	37	17	16	7	4	19	25	24	3
	7	11	6	5	s	s	s	s	s	s	—	2	—
	8	s	s	s	2	s	s	s	—	—	7	—	—
	9	—	5	1	s	—	—	—	—	—	s	—	—
(c) State of nutrition : percentage of starving flies	1924	—	—	—	—	—	—	16	21	8	5	2	3
	5	0	0	2	1	9	8	15	16	—	2	3	7
	6	0*	4	6	15	5	5	9	33**	13	19	17	6**
	7	—	8*	0**	—	—	—	—	—	—	—	—	—
	8	—	—	—	0**	—	—	—	—	—	38*	—	—
(d) Young flies : percentage of soft flies	1923	—	—	—	—	—	—	—	—	—	—	22	28
	4	32	19	14	20	21	9	11	11	4	7	7	2
	5	8	10	12	15	8	15	12	19	—	17	21	20
	6	25*	34	38	30	25	20	28	17**	19	11	21	25**
	7	—	15*	31**	—	—	—	—	—	—	—	—	—
	8	—	—	—	7**	—	—	—	—	—	32*	—	—
(e) Recognisable blood in flies : percentage	1923	—	—	—	29	25	23	17	17	19	26	18	17
	4	19	14	17	21	26	23	14	15	15	19	15	8
	5	7	14	16	22	17	13	14	10	—	8	12	9
	6	10*	7	9	14	23	18	14	11	21**	26	12	19**
	7	—	21*	0**	—	—	—	—	—	—	—	—	—
	8	—	—	—	27**	—	—	—	—	—	12*	—	—
(f) Non-mammalian blood : percentage of total blood	1923	—	—	—	10	24	24	23	21	18	48	70	28
	4	29	14	13	6	14	10	13	28	11	35	47	28
	5	23	19	17	0	7	10	27	30	—	35	47	14
	6	12**	0	11	27	56	15	14	2/2	80	52	33	15
	7	—	0	0	—	—	—	—	—	—	—	—	—
	8	—	—	—	3/4	—	—	—	—	—	80	—	—
(g) Rate of infection : percentage	1923	10	6	9	13	13	13	10	7	5	11	7	5
	4	9	19	12	16	17	16	18	11	9	7	8	6
	5	4	82	12	11	12	12	14	11	—	7	6	13
	6	2**	8	7	4	3	10	14	11**	15	14	10	6**
	7	—	0	0	—	—	—	—	—	—	—	—	—
	8	—	—	—	3/4	—	—	—	—	—	80*	—	—

The distance to the nearest primary focus was :—1923–25, continuous in both directions ; 1926, 300 yards ; 1927, 800 yards ; 1928, 2,500 yards ; 1929, 7,000 yards.

TABLE VI.

The results of the examination of *G. tachinoides* at the Road Pond (a secondary focus). The pool was fenced round and the game excluded in February 1925. The fringing thicket was cleared in March 1929 and the trees sapped.

[illegible]

TABLE VII—(Continued).

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
(c) State of nutrition: percentage of starving flies	1926	—	—	—	—	7	11	23	13	28	15	13	5
	7	5	2	7	1	2	9	5	0*	17	12	13	16
	8	13	5	13	4*	27	35**	11**	58**	37	21	—	—
(d) Young flies : percentage of soft flies	1926	—	—	—	—	37	20	22	29	25	18	9	34
	7	36	39	34	21	33	32	23	48*	17	9	12	26
	8	23	28	18	6*	22	15**	0**	8**	7	14	—	—
(e) Recognisable blood in flies : percentage	1926	—	—	—	—	15	17	7	15	2	20	12	28
	7	8	16	13	20	12	15	25	19*	14	30	30	19
	8	26	17	10	14*	8	15**	15**	13**	27	46	—	—
(f) Non-mammalian blood : Percen- tage of total blood	1926	—	—	—	—	25	33	27	17	2/4	62	46	18
	7	88	53	56	28	33	22	10	29	22	38	56	53
	8	59	65	57	57	60	1/5	7/7	0/3	74	31	—	—
(g) Rate of infection : Percentage	1926	—	—	—	—	4	8	13	14	6	16	9	8
	7	6	3	1	8	7	4	7	9*	19	10	5	6
	8	15	17	10	40*	27	0**	22**	21**	14	11	—	—

The distance to the nearest primary focus was :—1926–27, continuous ; 1928, 3,000 yards ; 1929, 8,000 yards.

STATUS OF ECONOMIC ENTOMOLOGY IN THE BRITISH SOLOMON ISLANDS.

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The Solomon Islands lie to the east of New Guinea and consist of an archipelago a thousand miles in length and about half this distance in breadth. They are divided politically into the Northern Solomons (formerly German but now administered under Mandate by Australia), and the British Solomon Islands Protectorate. This latter lies roughly between five and twelve degrees south of the equator and is believed to have been united both to New Guinea and Australia from at least the Triassic to the early Tertiary. As there is now a deep sea between the archipelago and the two land-masses, the former falls into the ancient section of the continental islands of Wallace.¹

The rainfall averages 150 inches, the maximum shade temperature has a mean of 90°F., and the relative atmospheric humidity averages 92 per cent.

The Group consists of six large islands ranging from 60 to 120 miles in length and many smaller ones, including the isolated Santa Cruz group to the east. The main islands are composed of both coralline and volcanic (chiefly diorite) rocks and hence exhibit a wide range of soil-types from coralline sands and red clay to alluvium. Evidence of former extensive elevation is provided in raised coral-beaches. The islands are generally covered with jungle and densely wooded to their summits which rise in places to over 8,000 feet. An exception to this is the central and western portions of the northern coast of Guadalcanal, which consist of grass plains and undulating downland.

So far, only parts of the coastal fringes have been agriculturally developed. Previously cotton, rubber and bananas were grown in addition to coconuts, but for the last twenty years or so the only important agricultural export has been copra, although a small amount of ivorynut (*Coelococcus salomonensis*) and so-called kauri pine (*Agathis macrophylla*) are exported. These are, however, respectively collected and felled as distinguished from being cultivated. Kapok has recently been taken up in a small way and, rather unsuccessfully so far, the tung-oil plant (*Aleurites fordii*), which does not seem to flourish.

Since coconuts are the only seriously cultivated crop, we shall confine our attention to the pests of this palm.

One of the most abundant insects to be found on the recently opened inflorescence is a Pentatomid, *Axiagastus cambelli*, Dist. In 1910 this bug was suspected by Froggatt² as the cause of immature nut-fall, which is now the most serious disease of coconuts in the islands, and in 1928 Tothill & Paine³ proved that it was responsible. These workers also found two Hymenopterous egg-parasites, which have recently been determined by the Imperial Institute of Entomology as *Anastatus* sp. (Eupelmidae) and *Microphanurus* sp. (Scelionidae). There is a marked inter-insular variation in the relative abundance of these parasites, Tulagi having a much higher percentage than Guadalcanal, and this island than Ysabel, which yielded no parasites from about 170 eggs collected in March 1932. The damage consists of punctures made on the fruiting branches by the proboscis of the bug resulting in such a loss of sap and such vascular congestion as to cause the young nuts to fall off at the pre- or early post-receptive stage. Nymphs as well as adults are harmful and cause pellucid stains resembling drops of oil on paper. As this insect seems only to have become

serious within the last five or six years, the position is comparable with that in the West Indies, where Myers⁴ has shown that indigenous insects have only comparatively recently become injurious on various economic plants which have been established for a long time.

Large cages of wire gauze or perforated zinc were placed around spadices with nymphal and imaginal *Axiagastus* inside, controls without any insects having also been set up. In addition, cellophane bags were placed round individual nuts, and it was found that there was a much higher fall of young nuts in the receptacles with the insects. Normal or physiological nut-fall causes about 67 per cent. of the nuts to fall in any case, as a result of the inability of the tree to nourish all the flower-buds produced. The corresponding figure in Fiji is 71.78 per cent. according to Taylor.⁵

Attempts to inoculate the young nuts with a solution of the salivary glands of the bug gave no higher figures than similar punctures with a sterile needle, which seems to indicate that the damage is, as suggested by Tothill, vascular congestion rather than a virus or a fungus introduced by *Axiagastus*.

It is noticeable that palms, perhaps adjacent to poor yielding ones, having nests or foraging parties of the red tree-ant, *Oecophylla smaragdina*, F., have, in nearly all cases, good crops. In marked contrast, other trees with colonies of any one of the three following ants, *Plagiolepis longipes*, Grst., *Iridomyrmex myrmecodiae*, Emery (quoted with doubt by Tothill as *I. rufoniger*), and *Pheidole oceanica*, Mayr, will invariably be bearing badly. All these ants, especially *Iridomyrmex*, show a strong antagonism to *Oecophylla*, which last will not live in harmony with any of them. Attempts to introduce nests of *Oecophylla* on trees occupied by one of the others met with complete failure, as swarms of the smaller ants attacked the red ant in mass formation and soon killed every caste in the nest.

Another insect which causes an appreciable nut-fall is a Pyralid moth, *Tirathaba rufivena*, Walk., a dun-coloured moth ranging from Ceylon to New Caledonia. Simmons⁶ incriminated this insect as long ago as 1925 as being the cause of some nut-fall; drought, excessive rain, fungi and a weevil, *Diocalandra*, were also blamed. The caterpillars of *Tirathaba*, whose preferred food are the male flowers, certainly do considerable damage to the young nuts, especially on spadices which (1) fail to open cleanly through the presence of a persistent strand of the spathe, (2) have the fruiting branches coming off at such an acute angle from the main stalk as to retain the shed male flowers in their axils, (3) produce nearly all-female flower-buds which are borne all the way up the branchlet except at the extreme apex, where the male flowers are.

In October 1931 the larvae were found feeding on the inflorescences of *Nipa fruticans*, Thunb., growing in a swamp on the island of Guadalcanal. This is apparently an additional host-plant to be added to *Elaeis*, *Phaseolus*, *Coix*, *Musa* and *Oreodoxa*. On *Nipa* the larvae were parasitised by what is taken to be the Braconid, *Apanteles tirathabae*, which is hyperparasitised by an undetermined polyembryonic Chalcidoid. On coconut the parasitism by the *Apanteles* is almost negligible, inclining one to the belief that *Nipa* is the original host-plant.

The *Tirathaba* adult is nocturnal and the female only is phototropic to artificial light. As the whole life-cycle occupies one month on the average, it coincides, more or less, with the production of new spadices.

Two small TINEOIDEA, *Stathmopoda nucivora*, Meyr., and *Decadarchis carpophthora*, Meyr., cause a very small amount of nut-fall. The larvae of the former are the more destructive and prefer the male flowers.

Another coconut pest is the Hispid beetle, *Brontispa froggatti*, Sharp, which both as larva and as adult damages the unfolded leaves between which its whole life-cycle is passed. Normally it is a serious pest only to palms less than ten years old, as after this age the trees are vigorous enough to withstand the damage caused

through the leaf-tissue being eaten. Many labourers have to be engaged in pouring from bottles a mixture of soap and tobacco juice so as to kill the insects in the as yet tightly furled leaves. Cutting out the affected leaves in all trees above about two years of age is practised in other parts of the tropics that suffer from allied Hispid. In these islands this would entail rigorous supervision, as the Melanesian native is singularly clumsy with the young fronds. Lead arsenate and Bordeaux mixture was tested here but is much more toxic to the foliage than the soap and nicotine and if used too dilute is not markedly more toxic.

One firm in less than a quarter of a century has spent about £80,000 in the control of this beetle, which is most rampant in the Russell Islands (Cape Marsh). It was here that Tothill and Paine took a red Gamasid mite (*Claenopsys* sp.) in association with the imago.

In November 1931 we took all stages of this insect on the unfolded leaves of *Ptychosperma* sp. (a local palm) at Teteri, Guadalcanal. This seems to be a new food plant, as coconut appears to have been the only one known previously.

Contrary to the procedure in Ceylon and Malaya, neither cultivation nor manuring is practised in the Solomons, and this is taken to be not unconnected in some cases with immature nut-fall, especially on estates which have received no treatment for upwards of twenty years. This is especially noticeable on areas adjoining grassy plains, where the soil required fairly constant treatment at the right time.

A Dynastid, *Trichogomphus semilinki*, Ritz., causes some injury to the crowns and young spadices. It has also been found on *Nipa*, *Poinciana regia*, mangrove and banana.

Malaria, chiefly subtertian, is fairly common, *Anopheles* (*Myzomyia*) *punctulatus*, Dönitz, being the only vector, but the percentage of infected mosquitos is relatively low on most estates. The early stages are generally passed in temporary accumulations of water such as collect in hoof-marks and cart-ruts, though we have found the larvae in a petrol tin full of rain-water. The adult has been observed biting at 11 a.m. in the plantations and at 3.30 p.m. indoors, where it may often be seen settling on warm dishes and cups, on which it usually chooses a shady position. The mosquito has a peculiar darting and more or less silent flight, which with its grey colour serve to distinguish it on the wing from the more abundant Culicines. The following, written in 1929 by Paine,⁷ is equally true to-day: "It must strike anyone visiting the group how inadequate is the screening of the average planter's house. In only two of the houses visited were the bathrooms properly screened, and judging by the abundance of *Anopheles* mosquitos in those bathrooms which I happened to use, stricter attention to screening would seem to be very desirable and necessary in anti-malarial work.

"One cannot blame residents of the country for neglecting to take all the precautions against malaria that a visitor would endeavour to take, but it seems quite certain that with a more vigorous inspection and a more adequate type of house-screening, the fever incidence could be very materially reduced, and discomfort from continual mosquito bites indoors completely avoided."

Filariasis is not very abundant except in the Santa Cruz Islands, where it is probably spread by *Aedes* (*Stegomyia*) *variegatus*, Doleschal, as is the case in Polynesia. In the outlying Sikiana group this insect is represented by *A. variegatus* var. *tongae*, indicating that into this Polynesian colony in Melanesia a Polynesian mosquito has been introduced.

House-flies (*Musca vicina*, Macq.) are now very common, especially on the plantations where both horses and cattle are usually kept. About twenty years ago this insect was apparently unknown, as the anonymous author of the British Solomon Islands Handbook for 1911⁹ states that they were then non-existent.

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Proclaimed noxious weeds are *Psidium guayava*, *Lantana* spp., and *Stachtarpheta dichotoma* (*indica* ?), while *Chrysopogon aciculatum* and *Imperata arundinacea* (lalang) are very harmful to coconut estates. Interesting ecologically is the fact that the latter grass is sometimes killed out by the Malvaceous *Sida retusa*, with a consequent improvement in the yield of coconuts. However, where lalang is absent, *Sida* is undesirable, as it is a gross feeder which uses up plant-food that would otherwise be available for the coconut palm; also it spreads very rapidly. In this connection there is a marked difference in the spread of *Psidium* in the Solomons and in Fiji, for in the latter group¹⁰ it grows much more luxuriantly and has led to the abandonment of some very large areas of coconut plantations—in some cases of more than a thousand acres.

We wish to acknowledge our indebtedness to the Imperial Institute of Entomology for determinations of many of the insects referred to in this paper.

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EGGS OF SOME ETHIOPIAN *ANOPHELES* MOSQUITOS.

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W.

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Towards the end of 1931 a study of the eggs of *Anopheles* mosquitos was commenced, primarily with a view to establishing any characters in the egg which may prove useful in differentiating closely allied species, and in particular those suspected of being concerned in the transmission of malaria.

The eggs of ten species of *Anopheles* are described and figured below: *mauritanus* var. *ziemanni*, Grünb., *implexus*, Theo., *pharoensis*, Theo., *theileri* var. *hancocki*, Edw., *christyi*, N. & C., *gambiae*, Giles (*costalis*, Theo.), *transvaalensis*, Carter, *funestus*, Giles, *marshalli*, Theo., and *moucheti*, Evans. Of these the writer has had the opportunity of examining specimens of *Anopheles gambiae* and *funestus* from four different regions in Uganda, namely, Kampala (3,900 ft.), Jinja (3,800 ft.), Mbale (4,000 ft.) and Fort Portal (5,100 ft.), and no local variations were observed. The eggs of two species dealt with in this paper have been previously figured by workers in other parts of the world. Edwards (1921) reproduced a drawing by Patton of the eggs of *Anopheles gambiae* (*costalis*) from Arabia, and Theodor (1924) published a drawing of those of *A. pharoensis* from Palestine. Both illustrations show eggs which in general structure are very similar to those of the same species in Uganda; the sculpture of the membrane is not figured. Individual variation within the eggs of a single adult was found to be constant in the case of *A. marshalli*, the three forms figured being represented in each of the three batches examined.

The drawings are in all cases on the same scale and were made from fresh eggs laid by previously identified adults confined singly in wide test-tubes; the writer has found that the details of the sculpture of the membrane are largely lost in preserved specimens. The eggs are figured from a dorsal view and a not quite completely lateral view. In most cases the adults from which the eggs were obtained were wild females collected in houses, but the females of *A. implexus* were blood-filled specimens captured in forest, and in the case of *A. christyi* the eggs were obtained from a female reared in the laboratory and fed on human blood. A table of measurements taken from a dorsal aspect is given in millimetres, together with a statement of the number of eggs laid by individual mosquitos.

I wish to take this opportunity to express my grateful thanks to Mr. H. Hargreaves, Government Entomologist, and Mr. G. H. E. Hopkins, Entomologist, for so kindly giving me facilities for carrying out this interesting study. To Mr. T. W. Chorley, of the Laboratory staff, for his assistance in obtaining eggs of *A. implexus* the writer's thanks are also due.

***Anopheles mauritanus* var. *ziemanni*, Grünb.**

Length, 0.5–0.57 mm.; breadth, 0.19 mm.

One of the most distinctive eggs of *Anopheles*, being almost entirely clothed in a membrane which opens along its median line. Viewed in a lateral aspect the egg appears almost flat on its dorsal surface between angular poles which project at each end. Air-floats comprising 24 to 26 chambers, slightly curved, lie obliquely and nearer the upper surface posteriorly.

UGANDA: Jinja, 10.iii.32.

Anopheles implexus, Theo.

Length, 0.57–0.62 mm.; breadth, 0.18 mm.

The egg of this species may be distinguished by its large size and the narrow striated frill at either end. These frills are attached to the membrane along its upper edge and originate near the base of the outermost air-cell and continue round the poles. The floats, which occupy a dorso-lateral position and consist of 20 to 24 air-chambers, are seen to cover approximately two-thirds of the lateral surface when the egg is examined from the side. In this position the concave dorsal surface and finely striated frill are clearly seen.

UGANDA: Kampala, 24.iii.32.

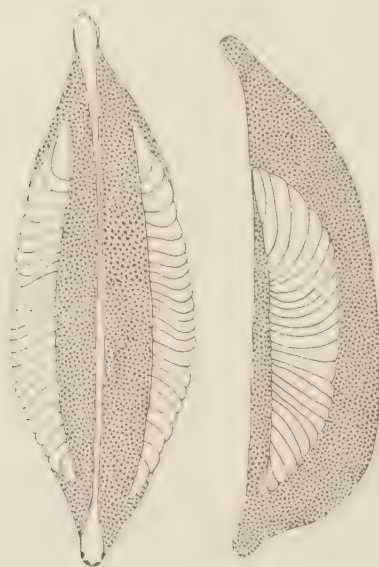


Fig. 1. Eggs of *A. mauritianus* var. *ziemanni*, Grünb.

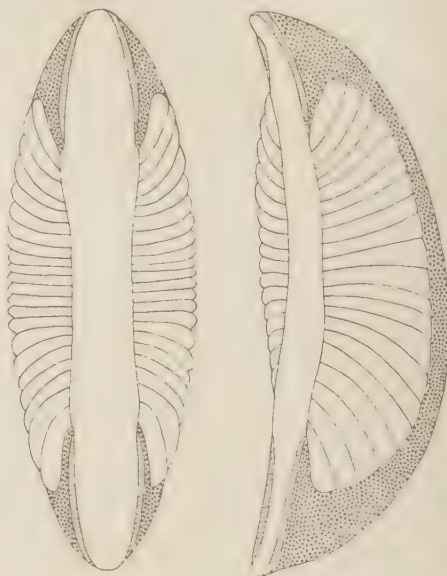


Fig. 2. Eggs of *A. implexus*, Theo.

Anopheles pharoensis, Theo.

Length, 0.5–0.52 mm.; breadth, 0.13 mm.

The egg of this species is very striking and when examined dorsally presents a unique appearance, as none of its membrane is visible. Its body is completely encircled by a number of air-pockets. The usual lateral floats, consisting of 26 to 28 chambers, are situated in the centre half and supplemented by a frill of tiny air-cells which arise a little above their outer extremity and continue round the pole.

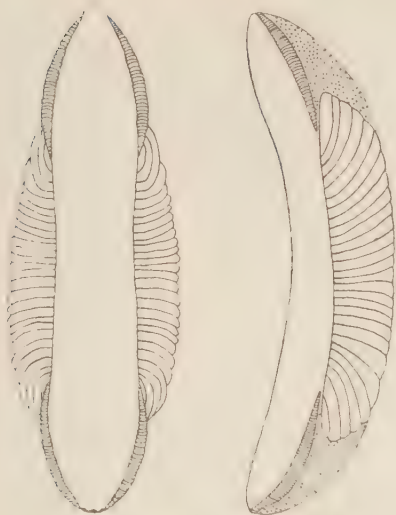
UGANDA: Jinja, 1.iii.32.

Anopheles theileri var. **hancocki**, Edw.

Length, 0.43–0.45 mm.; breadth, 0.12 mm.

This egg is among the smallest examined and closely resembles that of *A. funestus* but may be distinguished by the very fine form of the sculpture of its membranous sheath. The lateral floats comprise 13 to 15 air-cells. When seen from the side its concavity and rounded anterior end are very clear.

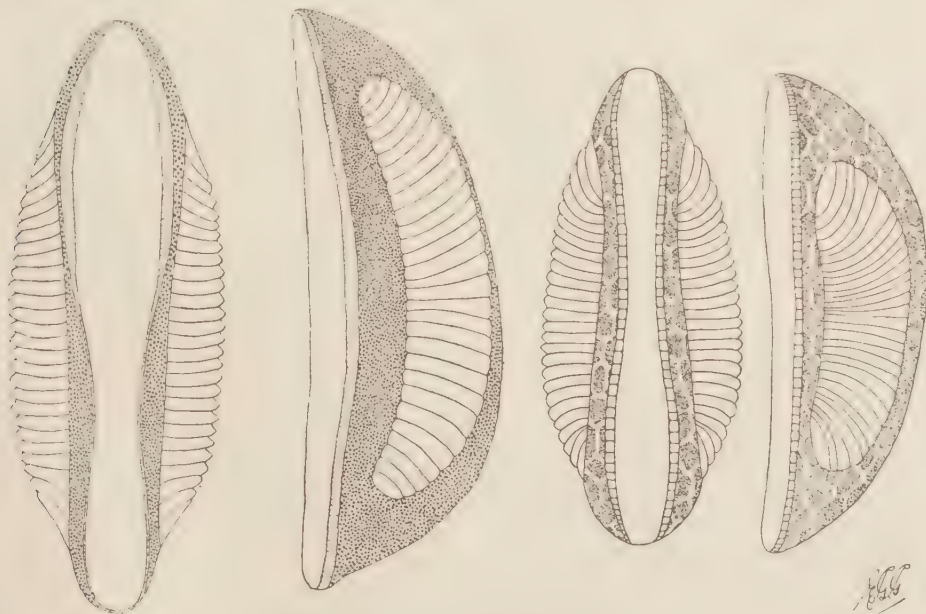
UGANDA: Kampala, 1.viii.31.

Fig. 3. Eggs of *A. pharoensis*, Theo.Fig. 4. Eggs of *A. theileri* var. *hancocki*, Edw.***Anopheles christyi*, N. & C.**

Length, 0.58–0.6 mm.; breadth, 0.18 mm.

A large egg with a loosely fitting membrane, which has a tendency to fold over at the anterior end and in lateral view appears to have a finely wrinkled edge. The floats are composed of 27 to 29 comparatively large air-cells.

UGANDA: Fort Portal, 9.i.32.

Fig. 5. Eggs of *A. christyi*, N. & C.Fig. 6. Eggs of *A. gambiae*, Giles (*costalis*, Theo.).

Anopheles gambiae, Giles (*costalis*, Theo.).

Length, 0.48–0.51 mm.; breadth, 0.21 mm.

A narrow rugose frill, apparently composed of minute air-cells, which encircles the egg on its dorsal surface, and the peculiar reticulated arrangement of the sculpture of the membrane seen by careful focusing make this species one of the most easily recognised. The side view shows the frill to be situated on the upper limit, and when examined dorsally the two sides of it are seen to be most widely separated at a short distance from the anterior end. The floats are situated in the middle of the lateral surface and contain 25 to 30 air-chambers.

UGANDA: Kampala, 6.viii.31.

Anopheles transvaalensis, Carter.

Length, 0.5–0.52 mm.; breadth, 0.16 mm.

This egg resembles those of *A. funestus* and *A. theileri* but may be separated by its size and by the form of the sculpture of its membrane. A pair of lateral floats, each having 13 to 15 air-chambers, are attached to the membrane and occupy two-thirds of the side of the egg. The dorsal surface is slightly concave with rounded ends.

UGANDA: Fort Portal, 16.xi.31.

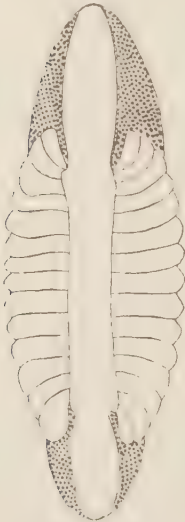


Fig. 7. Eggs of *A. transvaalensis*, Carter.

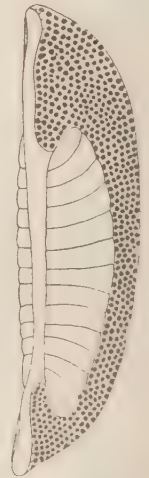


Fig. 8. Eggs of *A. funestus*, Giles.

Anopheles funestus, Giles.

Length, 0.45–0.48 mm.; breadth, 0.13 mm.

The coarsely reticulated sculpture of the membrane of this egg is a character of diagnostic importance. When examined dorsally the air-floats, which are convexo-convex and consist of 14 to 18 cells, are seen almost to meet on the median line. They are situated on the dorso-lateral surface nearer the posterior than the anterior pole.

UGANDA: Kampala, 6.viii.31.

Anopheles marshalli, Theo.

Length, 0.48–0.5 mm.; breadth, 0.15 mm.

This species shows considerable variation in the extent of the membrane. The three forms figured dorsally were found in one batch of eggs laid by a single mosquito.

This variability seems to be constant, for in two more batches examined each type was represented. The eggs differ in structure near their poles; in some specimens the membrane is fused, forming two enclosed areas; in others one end is open and bottle-necked; while in many cases both ends are open. The lateral floats, with 20 to 22 chambers, are uniform throughout.

UGANDA: Fort Portal, 6.x.31.

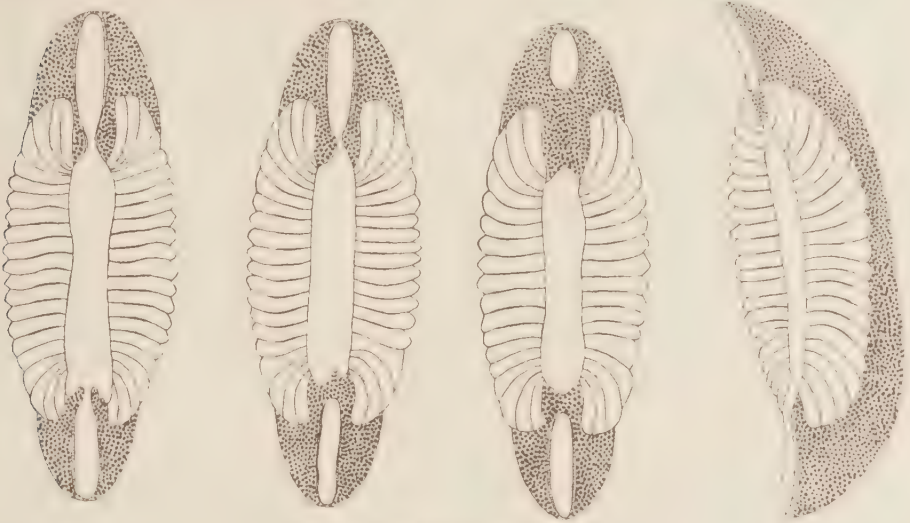


Fig. 9. Eggs of *A. marshalli*, Theo.

***Anopheles moucheti*, Evans.**

Length, 0.41–0.43 mm.; breadth, 0.16 mm.

The form of the membranous covering of this small egg is peculiar to this species. It nearly covers the egg and has a bluntly pointed process continuing inwards from near the end of the lateral floats. At the poles, extending to about the last cell of

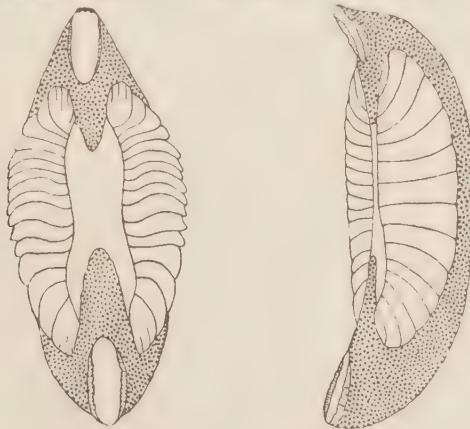


Fig. 10. Eggs of *A. moucheti*, Evans.

the air-floats (which consist of 15 to 17 unequal chambers) is a delicate finely-puckered collar of minute air-cells.

UGANDA: Jinja, 4.iii.32.

Species of <i>Anopheles</i>	Length	Breadth (including air- floats)	Breadth of egg	Length of lateral floats	Number of air-cells comprising floats	Number of eggs laid by different adults
<i>A. mauritanus</i>	0.5-0.57	0.19	0.13	0.38	24-26	246, 148, 194
var. <i>ziemanni</i>						
<i>A. implexus</i> ...	0.57-0.62	0.18	0.13	0.41	20-24	
<i>A. pharoensis</i> ...	0.5-0.52	0.13	0.12	0.36	26-28	111, 167, 197
<i>A. theileri</i> var. <i>hancocki</i>	0.43-0.45	0.12	0.09	0.24	13-15	72
<i>A. christyi</i> ...	0.58-0.6	0.18	0.13	0.4	27-29	84
<i>A. gambiae</i> (<i>costalis</i>)	0.48-0.51	0.21	0.14	0.33	25-30	118, 114, 126
<i>A. transvaal-</i> <i>ensis</i>	0.5-0.52	0.16	0.13	0.28	13-15	74, 82
<i>A. funestus</i> ...	0.45-0.48	0.13	0.11	0.28	14-18	107, 96, 118
<i>A. marshalli</i> ...	0.48-0.5	0.15	0.11	0.28	20-22	144, 108, 153
<i>A. moucheti</i> ...	0.41-0.43	0.16	0.13	0.28	15-17	126, 113

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OBSERVATIONS ON SOME DIPTERA AND MYIASIS IN KENYA COLONY.

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The study of Dipterous insects in Kenya Colony has been restricted, to a large extent, to the CULICIDAE and their relation to malaria, and to the TABANIDAE and the genus *Glossina* in connection with trypanosomiasis, the non-bloodsucking Diptera having received but little consideration.

"Blowflies" or "maggot-flies" are by no means uncommon in the Colony, and evidences of myiasis in its various forms are numerous. Symes & Roberts (1932) cite instances of the larvae of *Sarcophaga haemorrhoidalis* and of *Lucilia sericata* in the exposed brain substance of a woman; and of *Chrysomya bezziana* in an ulcer on the foot. *Cordylobia anthropophaga*, parasitic in the skin of man and other animals, is common, and *Auchmeromyia luteola* (in reality a blood-sucker in its larval stage) is distributed from the coast to the southern boundary of Abyssinia. The "sheep nasal fly" is extremely abundant, and many other larvae of *Oestrus* species have been recorded from game in the Colony.

Wounds, ulcers and sores in natives and in animals are often infested with maggots. I have seen, on several occasions, maggots in the ears, and in sores under the eyes, of native children, and in leg-wounds of native labourers. Still more frequently have I observed maggots in wounds of animals; they occur at the bases of distorted, and in the scars of broken, horns, in the lesions caused by tick-bites, in injured eyes, and in the soiled fleece of sheep. Animals on the point of death are often attended by myriads of sarcophagous flies, the vast numbers of *Chrysomya marginalis* in particular presenting an extraordinary sight.

The loss by actual deaths due to myiasis in Kenya does not appear to be great. Indeed there is little definite information on the subject; and for this reason, along with the belief that the disease is more common than it seems to be, investigations have recently been started. This contribution comprises some historical notes and preliminary observations on a few species of Muscoid flies, and on myiasis.

CALLIPHORIDAE.

***Lucilia cuprina*, Wiedemann.**

Patton & Evans (1929) include this species as one of the rare causes of semi-specific myiasis. It is interesting to note therefore the infestation of sheep by *L. cuprina* at an altitude of about 7,000 ft. above sea-level. The sheep were cross-bred Merinos with the laboratory numbers 3,919, 3,920, 3,921 and 3,922. No symptoms of any ailment appeared in this lot until after shearing in May 1931. All were in fairly good condition. The first sign of disease was a drooping of the ears, which on close examination revealed large septic sores. In the absence of treatment with disinfectant the sores seemed to spread down the side of the neck; and in an endeavour to arrest the spread of the septic semi-fluid mass, native herdsmen had made various incisions which were intended also for the drainage of fluid from the ears.

The following notes on the post-mortems of the sheep have been extracted from the observations made by the Chief Veterinary Research Officer, Mr. J. Walker, O.B.E., and by the Veterinary Research Officer, Mr. J. R. Hudson. I am indebted to both for assistance.

Sheep No. 3,919.

At the back of the right eye there was an open sloughing wound with a clean-cut incision extending to the sternum, which was made by the native herd for drainage of fluid from the wound. From the wound there exuded a foul-smelling fluid. The ears were infested with larvae and nymphae of the tick, *Rhipicephalus evertsi*. Maggots were present in the wound. Death was due to septic infection.

Sheep No. 3,920.

A sore, posterior to the right ear, showed the subcutaneous tissue to be a dirty, putrid and stinking mass with a large number of maggots. The lower jaw was swollen, and in an incision behind the ear was a quantity of purulent and bloody fluid. The ear was infested with larval *R. evertsi*. The lungs were hyperaemic and oedematous with foam in the bronchi. Septic infection was diagnosed as the originating cause of death.

Sheep No. 3,921.

This sheep was destroyed for post-mortem examination. Below the left ear was a suppurating wound containing many maggots. The left ear was infested with larval *R. evertsi* whereas the right ear contained no ticks, and there was no wound near it.

Sheep No. 3,922.

The animal died during the night and was examined on the following morning. It was reported to have shown circling movements. There was a local pyogenic infection in the region of the right petrous temporal bone. An open abscess extended into the central nervous system with consequent meningitis followed by generalisation and toxæmia. No maggots were found in the abscess.

The maggots from the above cases were extracted and further fed on meat. Those from No. 3,919 developed into adults of *L. cuprina*; those from No. 3,920 developed into *L. cuprina* and *Chrysomya chloropyga*; and those from No. 3,921 into *L. cuprina* and *Muscina stabulans*. All maggots were in the 3rd larval stage and infestation could only have taken place at the farm in the Ngobit district.

L. cuprina is widely distributed. I have collected specimens at Kabete, in Nairobi, in the Rift Valley, Uasin Gishu and the Thika districts. The adults obtained from the maggots of the above sheep were placed in a jar containing a piece of fresh meat. Oviposition took place on the following day. On the second day the eggs had hatched; on the fourth day the first stage larvae had developed into second stage larvae, and on the fifth day, 3rd stage larvae were present. These last were allowed to feed for two days, then placed in a mud-nest to pupate. Adults appeared on the twenty-third day. The average temperature was 65°F.

***Lucilia sericata*, Meigen.**

Symes & Roberts (1932) record larvae of this fly from a wound three days old. So far, I have not seen cases of animal myiasis caused by this species in the Colony.

***Chrysomya chloropyga*, Wiedemann.**

A common blowfly in the Colony, I have collected adults from the Kinangop Plateau (7,500 ft.), in the Rift Valley (6,300 ft.), in the Uasin Gishu Plateau (7,300 ft.), throughout the Trans-Nzoia (6,200 ft.), the Masai Reserve and the Kavirondo Reserve, at Kabete (6,200 ft.) and round Nairobi (5,500 ft.). As has been noted, maggots were found infesting the wounds of sheep. I have obtained maggots from wounds in cattle also. These flies are frequently found laying their eggs on putrifying meat. During July and August, when the climate is humid in parts of Kenya, the life-cycle of this species is completed within 37 to 40 days.

***Chrysomya marginalis*, Weidemann.**

I have obtained specimens from the Thika district only. Here, near Ol Donyo Sabuk, I observed extremely large numbers perched on the bushes near which was a beast in a very advanced stage of disease. Some larvae were collected from the malformed horns of this dying beast. Anderson (1923) records the species from Kabete.

***Chrysomya bezziana*, Villeneuve.**

From the information available to me at present, it appears that the first record of this fly in Kenya Colony is that of the larvae from an ulcer on the foot (Symes & Roberts, 1932). In this case of human myiasis the larvae had tunnelled some distance up the leg.

During August 1931, I received several lots of maggots collected from shoulder-wounds of cattle at the Laboratory farm, Kabete; and one lot was extracted from an injured eye of a sheep. In the latter case the maggots had penetrated the eyes, and the mass filled the eye socket and had affected the optic nerve. Most of the maggots were in the second larval stage, a few having reached the third stage. They were fed on fresh meat and they were afterwards placed in a mud-nest. When adults appeared they were identified as *C. bezziana*. It is noteworthy that Patton (1921) remarks that in Africa the larva of this species is rarely seen in the human body, but is common in the tissues of animals.

***Calliphora antarctica*, Schin.**

Although the fly is frequently found in the Colony I have seen the larvae only in a carcase of a dead beast. I have collected many flies near rubbish-heaps, garbage bins and in kitchens. Symes & Roberts (1932) record larvae of an unidentified *Calliphora* in a wound.

***Sarcophaga haemorrhoidalis*, F.**

This is another species which is present in abundant numbers throughout the Colony. It frequents kitchens, slaughter-houses and cattle-yards, laying its eggs in putrifying meat; it infests ulcers, as shown by Symes & Roberts (1932).

Larvae of some species of *Sarcophaga* have been passed in stools of humans in Kenya.

On one occasion I have collected maggots of *S. haemorrhoidalis* from a broken dove's egg near Kabete. I have no record of its infesting wounds, etc., in animals in the Colony.

***Cordylobia anthropophaga*, Grünberg.**

Universally known as the "tumbu fly of Africa" this species was locally known, in the earlier days of railway construction in Kenya, as the "Maungu fly" because of the numerous cases of infestation of man at Maungu on the Kenya and Uganda railway. Ross (1904-10) records cases of myiasis produced by the larvae and states that the fly appeared to haunt latrines especially. Anderson (1909) obtained specimens from a dog at Mombasa, which harboured over 100 larvae in the subcutaneous tissue. These larvae were found in every part of the body except the back; the lips and ears were badly affected. Sturdy (1909-10) points out the differences in infestation of dogs at Mombasa and in the Northern Frontier Province of the Colony. In the latter area the maggots were much fewer and did not exceed 20 in the highest infestation. Two dogs had maggots on the plantar surfaces of the feet just behind the central pad. The scrotum, lips, and ears were free, the maggots being on the outside of the thighs and along the sides.

C. anthropophaga is widely distributed in Kenya. Maggots have been sent from Lamu, Mombasa, Fort Hall, Nairobi, Kabete, Trans-Nzoia and the Northern Frontier Province. In the report of the Medical Entomologist for the year 1928 "*Cordylobia anthropophaga* occurred in relative abundance during the year in Europeans in the Nairobi district. Heavy infestations were reported on dogs at Kitale."

Recently a very large number of cases of infestation of dogs have been reported to me from Nairobi and the surrounding districts. Maggots from horses, rats, natives and from Europeans have been received. There appear to be fluctuations in the numbers of infestations. A relative abundance of cases occurred in Nairobi during 1928, and another widespread outbreak exists at the present time. Does the fly increase more rapidly in some years; and have the intervening years between 1928 and 1932 shown a definite lull in the activity of the species in certain localities?

***Cordylobia (Stasisia) rodhaini*, Geddoelst.**

Larvae of this species have been recorded from the arm of a European in the vicinity of Ol Donyo Sabuk in the Colony; and from small rodents in the rain forests of equatorial Africa (Symes & Roberts, 1932).

***Cordylobia* sp.**

Another female specimen of a fly, closely resembling *A. luteola*, was caught at the mouth of a warthog's burrow near Ngong. The live specimen was put into a tube and immediately laid a batch of 28 pear-shaped eggs. Larvae hatched out in two days. All attempts at feeding these larvae on normal and on wounded skins of live animals (mice and rabbits), and on fresh meat, were without success. The warmth of live animals seemed to stimulate rapid movement, and attempts at burrowing, by the larvae. On fresh meat, all died.

***Auchmeromyia luteola*, Fabr.**

The larva of this fly does not, strictly, produce myiasis; it is a blood-sucker. The fly is fairly widely distributed throughout the Colony; it is particularly common at Mombasa and in the Northern Frontier Province. Cattle are frequently attacked by the larva in the Mombasa district. The adult seems to have some predilection for dry districts. The majority of adults in my collection have been obtained near, or in, the burrows of warthogs (*Phacochoerus aethiopicus*) and several specimens have been caught in a tsetse-fly trap near Isiolo.

MUSCIDAE.

***Muscina stabulans*, Flin.**

As stated above, this species occurred along with *L. cuprina* in a double infestation of a wound in a sheep. I have also obtained larvae from the nostrils of a bullock affected with trypanosomiasis and some other undiagnosed disease which caused profuse, foul-smelling discharges from the nose.

M. stabulans occurs at Kabete, Mitubiri in the Thika district, and at Ngobit.

***Synthesiomyia nudiseta*, Stein.**

This species of fly attracted my attention when a specimen in the laboratory laid a batch of eggs on a piece of meat intended for maggots of *Chrysomya bezziana*. It has been collected on five occasions from the post-mortem room at Kabete, but so far as I am aware, it has not been implicated in the production of myiasis.

At a room temperature of 62 F., the eggs hatched out on fresh meat on the second day after oviposition; second-stage larvae appeared on the fourth day and third-stage larvae on the sixth day. The fully-fed larvae were placed in a mud-nest on the eleventh day, the adults emerging on the thirtieth day.

OESTRIDAE.

Oestrus ovis, L.

The "sheep nasal fly," as the species is popularly called, is a very common parasite in the Colony: particularly in the Rift Valley and on the Laikipia Plateau. As early as 1905, Sturdy stated "the larvae of *Oestrus ovis* cause considerable loss to stockowners in various parts of the Protectorate, more particularly in the Machakos district and in the humid atmosphere of Muhoroni. It is common on the Nandi Plateau and in the Rift Valley. In many cases the frontal sinuses have been found packed with larvae, and in one case as many as 58 larvae were taken from the sinuses of one sheep. Subdural abscesses, due to irritation set up, are of frequent occurrence. This pest is indeed a serious one for the sheep farmer, as treatment becomes difficult, for no sooner is one brood of larvae ejected than the animal is re-infested. Although the mortality cannot be considered a high one, yet the loss accruing from the falling off of conditions is decidedly serious."

Simpson (1908) records a similar *Oestrus* in the nasal cavities of kongoni (*Bubalis cokei*) and waterbuck (*Kobus ellipsiprymnus*).

Oestrus variolosus, Loew.

In 1909-10 Anderson reported that maggots of a fly obtained from the heads of sheep slaughtered in Nairobi were hatched out and identified as *Oestrus variolosus*. Patton (1921) states that the maggot is commonly found in the Jackson's race of the Lelwel hartebeest (*Bubalis lelwel jacksoni*), a common antelope in Kenya. Symes & Roberts (1932) record the maggot from the nasal cavities of Coke's hartebeest in the Colony.

Probably the *Oestrus* sp. seen by Simpson and referred to above was the larva of *O. variolosus*.

Bedford (1927) states that Geddoelst includes Kenya Colony in the distribution of this species. On referring to Geddoelst (1918) the parasite is recorded from *Bubalis major*, a western hartebeest and not found in Kenya Colony.

Oestrus asininus, Brauer.

Anderson (1923) records a specimen collected by Dr. Beven from Neboi in the Northern Frontier Province on 19.vi.1922.

Gastrophilus intestinalis, De Geer.

This species of "bot" has been collected on several occasions from horses in Kenya Colony, particularly in the districts of Nairobi and Naivasha. Probably the preceding *O. asininus* recorded by Anderson is a variety of *G. intestinalis*.

Gastrophilus nasalis, L.

I collected a number of "bots" of this species from a horse brought from Nanyuki to the Veterinary Research Laboratory, Kabete, on 2.x.1931.

Gastrophilus pecorum, F.

From a Grevy's zebra (*Equus burchelli grevyi*) and from horses, I have collected numerous larvae of this fly. Bedford refers to larvae collected at Kajiado from the oesophagus of a horse which had been imported from South Africa.

Gastrophilus haemorrhoidalis, L.

A number of larvae strongly resembling those of *G. haemorrhoidalis* have been collected from a donkey and from two Grant's zebra (*Equus burchelli granti*). There are some minute variations and a further study of these appears necessary.

Gastrophilus ternicinctus, Gedoelst.

Bedford (1927) records specimens, from Mr. G. B. Purvis, taken from the stomach of a zebra in the Uasin Gishu, Kenya Colony.

Gastrophilus sp.

A species submitted to Gedoelst for description is recorded by Bedford (1927). Specimens were collected from the duodenum, intestines, and rectum of a zebra from the Uasin Gishu district. The description of this species is not available to me at present.

Gyrostigma meruense, Sjöstedt.

The only record of the larva in the Colony appears to be one by Bedford (1927), who states that it has been recorded from *Rhinoceros bicornis* (the black rhinoceros) from Nyasaland, Kenya Colony, and Tanganyika Territory.

Gedoelstia cristata, Rodhain & Bequaert.

Symes & Roberts (1932) record the larva as having been taken on three occasions from the nasal cavities of Coke's hartebeest.

Gedoelstia hassleri, Gedoelst.

Bedford (1927) received larvae, from Mr. G. B. Purvis, taken from the nasal cavities of a hartebeest in the Colony; and Symes & Roberts record it from the same host as the preceding parasite.

Hypoderma spp.

Cattle imported into the Colony from Britain have been observed, at the Veterinary Quarantine at Nairobi, to harbour the warble-fly maggot. It is customary for the officer in charge to dislodge and destroy them. Some cattle, however, were allowed, at one time, to be conveyed to various farms up-country and were isolated on the owners' premises. It is conceivable that at least a few of these animals harboured the warble. Yet there appears to be no evidence of the existence of the adult fly in the Colony; and it would seem that, as in South Africa, the conditions are unfavourable to the development of the maggot and the increase of the species.

In conclusion I wish to record my gratitude to Sir Guy A. K. Marshall and the staff of the Imperial Institute of Entomology for assistance in the identification of some of the above and other species of Diptera.

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NOTES ON THE NATURAL CONTROL OF *COLEOPHORA LARICELLA*, THE LARCH CASE-BEARER.

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(With an Appendix by C. FERRIÈRE, D.Sc.)

1. Introduction.

The Tineid moth, *Coleophora laricella*, the larva of which is known as the Larch Case-Bearer, has long been recognised as a very serious forestry pest in Europe. It is found in Europe from the French Alps and Italy, throughout Austria and Germany, Holland, Southern and Central Russia, as far as Finland and the Carpathians. It no doubt occurs wherever *Larix europæa* is native and it has also been introduced with it into Sweden and Great Britain. It was discovered in Massachusetts in 1886, where it had probably been present for some time undetected, and has since spread through the North-Eastern United States as far west as Michigan. In Canada it has been recorded from Ottawa, Quebec, and New Brunswick. Yano (1919) records it as abundant on *Larix leptolepis* in Japan, where it has, presumably, been introduced.

In Canada *Coleophora laricella* has, in recent years, been responsible for very great injury to larch plantations; consequently, in 1928, the Imperial Institute of Entomology, at the request of the Dominion Entomologist, undertook to investigate the parasites of the moth in Europe, with a view to their utilisation in Canada.

Owing to the pressure of other work it has only been possible to make a preliminary study of the subject. Soon after the commencement of the work it became clear that one parasite, *Angitia nana*, was considerably more promising than the rest and if this species can be established in Canada it will probably be advisable to await results awhile before considering further introductions. Consequently, at the request of Dr. W. R. Thompson, the present paper is being published in spite of its incomplete nature.

So much has been written on *Coleophora laricella* that it is hardly necessary here to give more than a brief résumé of the life-history. A good up-to-date account of the life-history in Europe is given by Escherich (1931) pp. 188-193. Details of the life-history, as it occurs in the United States, are given by Herrick (1912), and an account of the situation in Canada will be found in the paper by Baird (1923).

The life-history in the West of England is briefly outlined below. The exact times of emergence and hatching would, of course, vary slightly according to localities, but there is never more than a single brood in a year. The eggs are laid singly on the leaves, mostly during the latter part of June and early July. The larvae hatch in about 10-14 days and burrow directly through the floor of the egg into the leaf tissue, where they live as miners for 6-8 weeks, at first feeding little and growing very slowly. After the first moult in August they feed more rapidly, and the mine, which has hitherto been almost invisible, is now clearly seen. In the middle of September they emerge from their burrows, and each larva makes itself a case out of an excavated larch needle, either cutting off the one in which it has been feeding and using it for this purpose, or else going in search of a new leaf and mining it out. After constructing its case the larva may continue feeding for another two or three weeks. In October the larvae move to the twigs, firmly attaching their cases with silken threads to the bases of next year's buds, and there they hibernate. As soon as

the buds open in April the larvae recommence feeding. This is the time when the greatest damage is done, each larva destroying a large number of young leaves. When the case becomes too small for the rapidly growing larva it is split lengthwise and enlarged by the insertion of a silken seam. Pupation commences about the second week in May and takes place within the case, which is attached to the leaf whorls or twigs for this purpose. The pupal period lasts about three weeks, the first moths appearing early in June.

In Europe the chief food-plant is *Larix europaea*. It is frequently stated that the Japanese larch, *L. leptolepis*, and the Siberian larch, *L. sibirica*, are more or less immune, but this is now known to be erroneous. Infestation of *L. leptolepis* has now been recorded in Japan, Italy, and Central Europe, and I have seen this tree badly attacked in both Cambridgeshire and Gloucestershire. In North America the native tamarack, *L. laricina*, is also attacked.

Trees from 10 to 40 years of age tend to be the most severely infested and it is the younger trees which suffer most. Besides the direct injury to the foliage a prolonged attack results in a shorter growing period and delayed foliation, and the consequent weakening of the tree predisposes it to the attacks of other organisms, particularly larch canker (*Dasyscypha calycina*).

Heavy infestations appear rare in England, and I have not so far seen an attack in this country which could be called serious.* In Central Europe, however, the attacks are often much more severe. I myself have seen well-grown larch trees at Heiligenblut in the Carinthian Alps, 6,000 feet above sea-level, having almost every needle shrivelled by case-bearers: the trees appearing as if they had been scorched by fire.

Although a lime-sulphur spray has been found satisfactory (Herrick) in controlling the pest on isolated ornamental trees, this method is obviously out of the question where large areas of forest are concerned. Nor does the pest seem any more amenable to treatment by modifications in forestry practice. Such measures as the planting of mixed woods instead of pure stands of larch do not seem to hold out any promise, for, according to Escherich, larches in mixed stands are attacked as freely as in pure. Consequently, a satisfactory biological method of control would be of the greatest value.

2. List of Parasites Reared at Farnham House Laboratory.

ICHNEUMONOIDEA.—Ichneumonidae: *Angitia nana*, Grav. Braconidae: *Sigalphus caudatus*, Nees (?),† *Microdus pumilus*, Ratzb.‡

CHALCIDOIDEA.—Eupelmidae: *Eupelmus* sp. Pteromalidae: *Habrocytus* sp., *Eurydinota* (*Pteromalus*) *laricinellae*, Ratzb.† Eulophidae: *Cirrospilus* (*Eulophus*, *Entedon*) *pictus*, Nees, *Eulophus metalarus*, Walk.,† *Dicladocerus westwoodi*, Steph.,† *Chrysocharis* (*Entedon*) *laricinellae*, Ratzb.,† *Chrysocharis* sp.

One or two examples of several other species of parasites were obtained in the cages containing infested larch shoots, but since the evidence that they are parasites of *C. laricella* is not completely satisfactory they have been omitted from the foregoing list. They are as follows: *Hemiteles* sp. (near *sordipes*, Grav.), 1 specimen, 20th June 1930, Forest of Dean, Glos.; *Gelis pulicarius*, F., 1 specimen, 27th June 1930, Forest of Dean, Glos.; *Lissonota* sp., 1 specimen, 1st May 1931, St. Martin de Vesubie (A.M.), France; *Eubadizon extensor*, L., 1 specimen, 6th June 1930, Forest of Dean, Glos.; *Psychophagus omnivorus*, Walk., 3 specimens, 2nd–6th June 1930, Forest of Dean, Glos.; *Pteromalus deplanatus*, Nees, 1 specimen, 27th June 1930, Forest of Dean, Glos.

* Mr. H. S. Hanson tells me that he has seen very severe infestations in Devonshire.

† Not previously recorded from *C. laricella*.

‡ Not previously known in Great Britain.

3. List of other Species previously recorded from *C. laricella*.

ICHNEUMONOIDEA.—Ichneumonidae: *Hemiteles pulchellus*, Grav., *Pimpla examinador*, F., *P. turionella*, L., *Omorgus tumidulus*, Grav., *Angitia virginalis*, Grav.
Braconidae: *Bracon guttiger*, Wesm.

CHALCIDOIDEA.—Chalcidae: *Entedon laetus*, Ratzb.

4. Notes on the Structure and the Biology of the more important Species.

Angitia nana, Grav., is a mainly black Ophionine of about 3 mm. long. The tegulae, greater part of the trochanters, anterior coxae, and a broad median band on the tibiae are whitish. All our specimens have the hind femora blackish, not red as stated by Morley and Schmiedeknecht. The chief structural characteristics are shown in the illustrations (figs. 1-2). Our examples, as shown in fig. 2 *b*, have



Fig. 1. *Angitia nana*, female.

the ovipositor definitely longer than the petiole and from one-third to one-half the length of the abdomen. This is contrary to the descriptions of Schmiedeknecht and Morley, who both state the ovipositor to be one-quarter the length of the abdomen.

A. nana is not likely to be confused with any other previously recorded parasite of *C. laricella*. From *Omorgus tumidulus* it is distinguished at a glance by its small size and the absence of red on the abdomen, as well as by many more fundamental characters. From *A. virginalis* it can be separated by the smaller size, absence

of red markings on the legs, and by the broad vertex and absence of constriction behind the eyes. The specimens we have reared show little variation except as regards the areolet, which is quite useless as a character. While well developed in the majority of our specimens it is minute and incomplete in many others, and

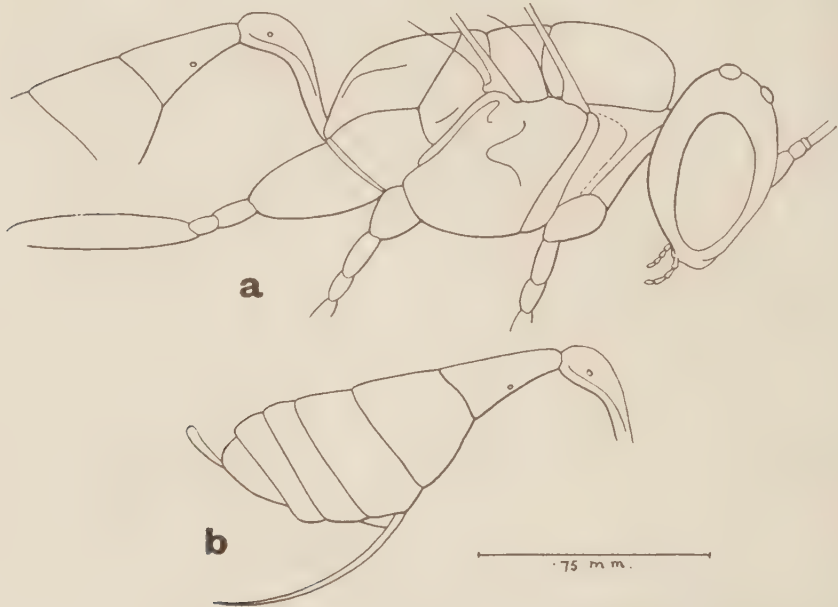


Fig. 2. *A. nana*, ♀: a, lateral view of thorax; b, lateral view of abdomen.

in a few it is entirely absent (see fig. 3 a-c). Some specimens have the areolet well developed in one wing and completely absent in the other. To make this character the ground for separation of a distinct genus, as Schmiedeknecht has done, seems quite unscientific and, when using his keys, several of our specimens run to *Diocetes elishae*, Bridg. Morley, quite rightly, includes *elishae* in the genus *Angitia*, but since the areolet cannot apparently be regarded even as a satisfactory specific character, and since all our specimens whether with or without areolet have the hind femora black, it seems very doubtful whether *elishae* and *nana* can be regarded as distinct any longer.

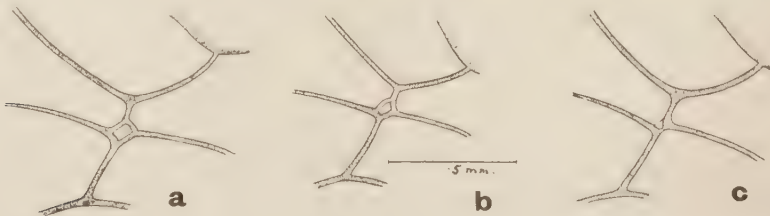


Fig. 3. *A. nana*: a, b, & c, areolet of fore wing to show variation within the species.

Somewhat similar difficulties present themselves when one attempts to distinguish between *A. nana* and *A. coleophorarum*, Ratzb. The original description of the latter species is so inadequate that it is impossible to know to what it referred. Morley describes it as lacking black markings on the hind tibiae, and this character,

together with the larger size and slightly shorter terebra (5 mm.), separates it from *A. nana*. *A. parvula*, Grav., is also separated by similar unreliable characters of colour and size. Indeed the characterisation of the whole of Schmiedeknecht's group I of *Angitia*, which contains *parvula*, *coleophorarum*, and four other species, is very unsatisfactory. Meanwhile, pending a thorough systematic study of this complex, all our specimens from *C. laricella* must be regarded as *A. nana*.

Angitia nana was the most abundant and widely distributed parasite obtained. It is already known as a parasite of *C. laricella* and has been recorded from Belgium, Sweden, France, England, and Germany. In our collections it was most abundant in the West of England. The highest degree of parasitism, 68 per cent., was recorded from Staple Edge Plantation, Forest of Dean, Gloucestershire, 1929-30, a plantation of trees of between 11 and 18 years of age on a good loamy soil at 700 feet above sea-level. Other samples in the immediate neighbourhood gave 50 per cent. and 45 per cent. In the following season the parasitism in this locality was found to be lower (e.g., 12 per cent.), but the data obtained were not so extensive and therefore the figures are not really comparable. In other parts of the Forest the parasitism, mostly on trees of a similar age, was found to vary between 12 and 25 per cent.,

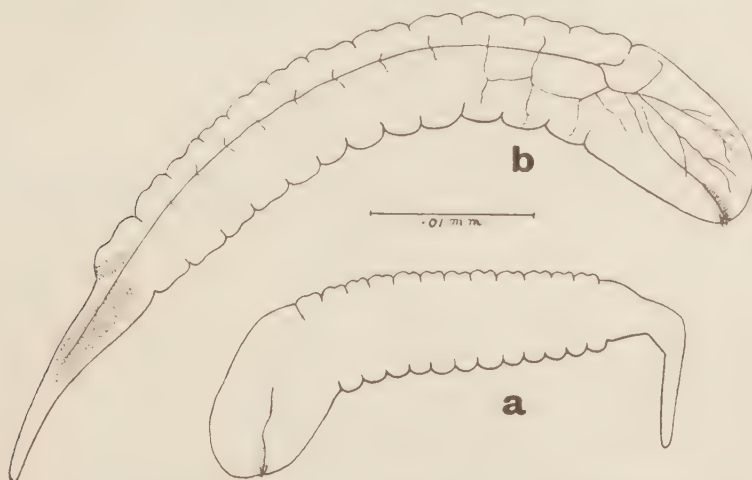


Fig. 4. *A. nana*, first-stage larva; a, on hatching; b, after feeding has commenced.

and a similar degree was found at Ludlow, Shropshire. On much older trees, less heavily infested with case-bearer, a lower parasitism of about 10 per cent. was recorded. There did not appear to be any significant difference in degree of parasitism between the case-bearer populations on Japanese and European larches when growing in the same area; *Angitia nana* was also reared from material collected at Wilbraham, Cambridgeshire, but was comparatively rare. Dissection of 230 individuals from one consignment yielded only one *Angitia* larva while in another case a parasitism of 1 per cent. was recorded. A quantity of case-bearer material received from St. Martin de Vesubie, Alpes Maritimes, France, in September 1930, yielded a single larva, probably referable to this species, though no adults were reared.

The adults of *A. nana* first appeared from material in the insectary on 2nd June and continued emerging for about two to three weeks. Under natural conditions in the west of England emergence would commence a few days later. In the south-east it is probably earlier. Morley (V, p. 183) records the capture of a specimen at Hastings on 18th May 1900. They continue on the wing till about 10th to 15th September. The eggs are laid in the young larva in its mine. Although most of

the eggs are no doubt deposited during July and the first half of August. I have found females captured in the open on 28th August still containing from 50 to 100 well-developed eggs.

The first-stage larva floats in the haemocoel of the host and is of the usual Ichneumonid type (figs. 4, 5). A detailed description is not necessary. I have never found more than a single larva in a host. The parasite remains in the first instar, feeding very little, till the host recommences activity in the spring, when it

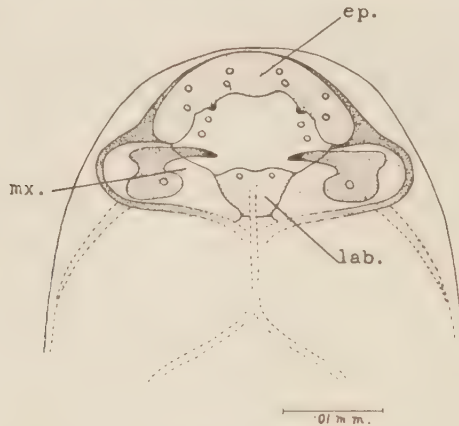


Fig. 5. *A. nana*, first-stage larva. Ventral view of mouth-parts and head structures: *ep.*, epipharyngeal region; *lab.*, labial region; *mx.*, maxillary region.

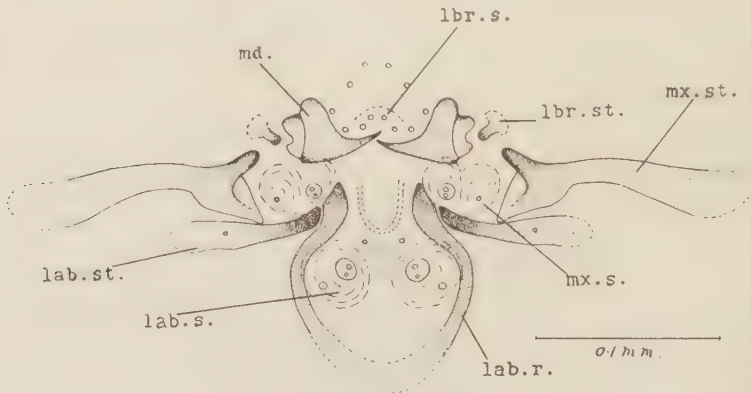


Fig. 6. *A. nana*, mature larva. Ventral view of mouth-parts and head structures:
md., mandible; *lbr. s.*, labral sensillae;
lbr. st., labral strut; *mx. s.*, maxillary sensillae;
mx. st., maxillary strut; *lab. s.*, labial sensillae;
lab. st., labial strut; *lab. r.*, labial ring.

passes rapidly through the remaining stages. Parasitised *Coleophora* larvae do not pupate in May, when the healthy individuals are spinning their cocoons, but remain active and consequently are easily separable. The parasitised larvae although active do not appear to consume much food. Finally, the *Angitia* larva kills its host and pupates in the case beside the empty skin. The mouth-parts and head structures of the last stage larva are illustrated in fig. 6. They are closely similar in general plan to those of other Ophionine Ichneumonids, described in a previous paper (Thorpe, 1930).

Angitia nana has been recorded from the following hosts :—

PSYCHIDAE : *Psyche opacella*, H.S. TINEIDAE : *Fumea casta*, Poll., *Mompha fulvescens*, Hw., *M. conturbatella*, Hb. (?)

If *clisae* is indeed a synonym then the following should be added to this list : *Onix scoticella*, Stt., *Nepticula aucuparia*, Frey, *Coleophora suaedivora*, Durr. (*flavaginella*, Meyr.), *C. atricoella*, Zell., *C. discordella*, Zell., *Lithocolletis emberizae pennella*, Bouché, *Gracilaria tringipennella*, Zell., *Bedellia somnulentella*, Zell., *Platyedra vitella*, Zell. *A. coleophorarum* is listed from *Coleophora* sp., and *Lithocolletis syringella*, F. Dalla Torre also records *Nematus gallicola* as a host, but this is almost certainly a misprint, as Ratzeburg has no mention of it, although *A. chrysosticta* and *A. curvicauda* are known as *Nematus* parasites. Leonardi has copied this error. Morley records *A. parvula* from *Eucosma aemulana*, Schlag. (*tripoliana*, Barr.).



Fig. 7. *Chrysocharis laricinellae*, female.

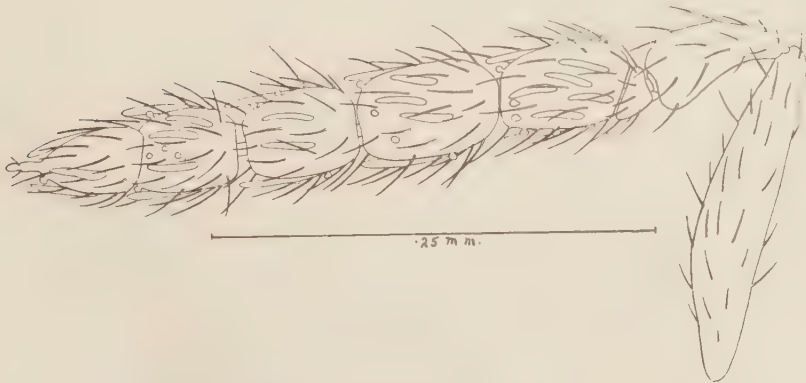


Fig. 8. *C. laricinellae*, ♀: antenna.

Three species of EULOPHIDAE have been reared from *Coleophora laricella* in considerable numbers; they are *Chrysocharis* (*Entedon*) *laricinellae*, Ratzb., *Dicladocerus* (*Eulophus*) *westwoodi*, Steph., and *Eulophus metalarus*, Walk. The first two are brilliant metallic green insects with a superficial resemblance to each other. *Chrysocharis* is characterised by the small size, the comparatively short and rounded wings, and by the very short and strongly broken subcosta (submarginal) vein.

Dicladocerus has long wings, the subcosta is more or less smoothly curved and is about equal in length to the marginal. The antenna of the male with its two large lateral branches is a striking feature (fig. 12, a), and additional characters will be found in the detailed structure of the wings. *Eulophus metalarus* in general resembles *Dicladocerus* but can be separated from it by its smaller size and by its dark bronze green coloration, sometimes almost blackish. The wings also appear darker, owing to the relatively larger and more closely spaced hairs, and in the female there is

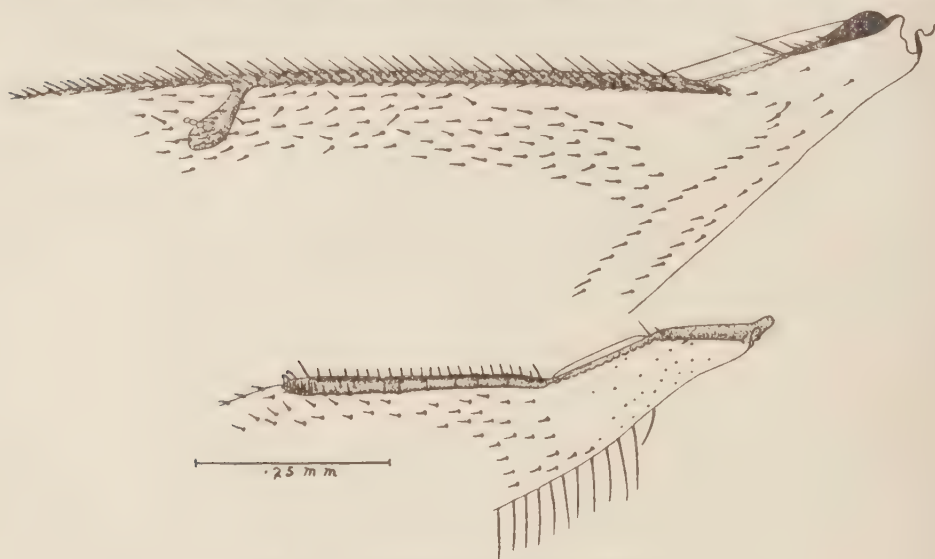


Fig. 9. *C. laricinellae*, ♀: detail of wings.

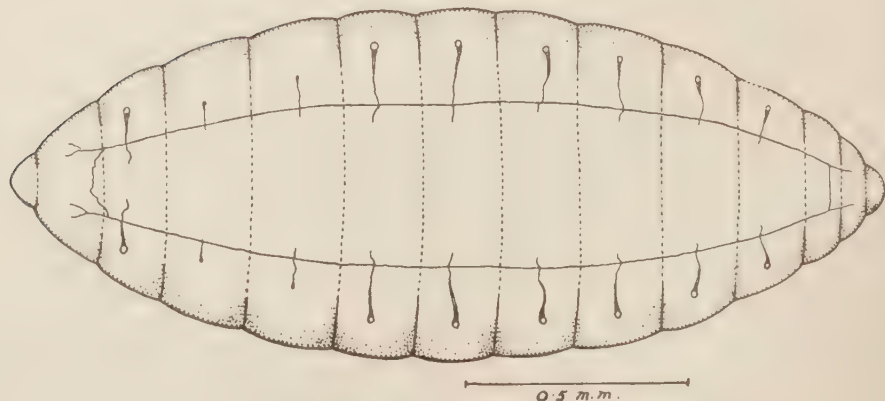


Fig. 10. *C. laricinellae*, mature larva.

a faint smoky patch below the tip of the radius. The chief distinguishing character however is found in the antenna of the male, which bears three lateral branches (fig. 14, a). Separation from the other Chalcidoidea attacking *C. laricella* will be rendered easy by Dr. Ferrière's key (Appendix).

Chrysocharis laricinellae, Ratz. (figs. 7, 8, 9) was reared from material collected in the Forest of Dean; at Ludlow, Shropshire; at Wilbraham, Cambridgeshire; and in the South of France. The insect was previously known only from Germany

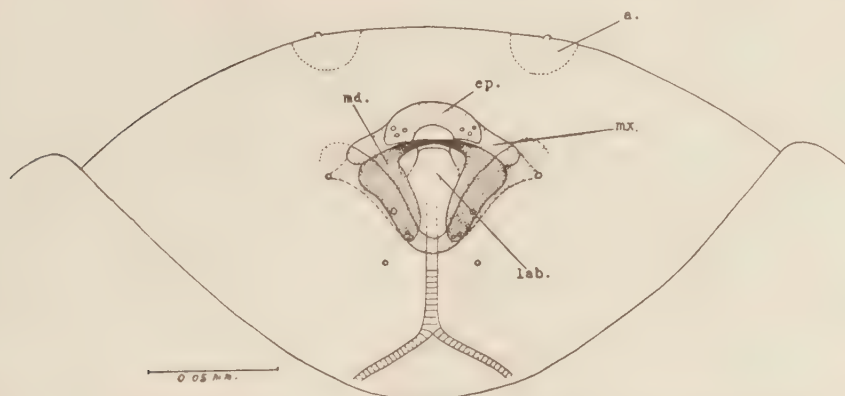


Fig. 11. *C. laricinellae*, mature larva. Ventral view of mouth-parts and head structures: *a*, antenna; *ep*, epipharyngeal region; *lab*, labial region; *mx*, maxillary region; *md*, mandible.



Fig. 12. *Dicladocerus westwoodi*: *a*, antenna of ♂; *b*, antenna of ♀; *c*, mandible of mature larva.

and North Italy. The highest parasitism recorded was 5·6 per cent. in a consignment of 1,375 *Coleophora* collected in the Forest of Dean in November 1930, but so far as our experience goes the average figure would be somewhere nearer 1·5 per cent. It is an internal larval parasite. While normally a primary, some of our observations suggest that it may act as a secondary under certain conditions and it will be inadvisable to attempt introduction without further careful studies on this point. The mature larva has seven pairs of functional spiracles (fig. 10). The mouth-parts and head structures are shown (fig. 11). It appears that the winter may be passed either as a mature larva or as a pupa. Emergence commences at about the end of April and continues into July. There is probably a partial second brood. Adults were observed in the field up to the end of August. *Coleophora laricella* is the only known host.

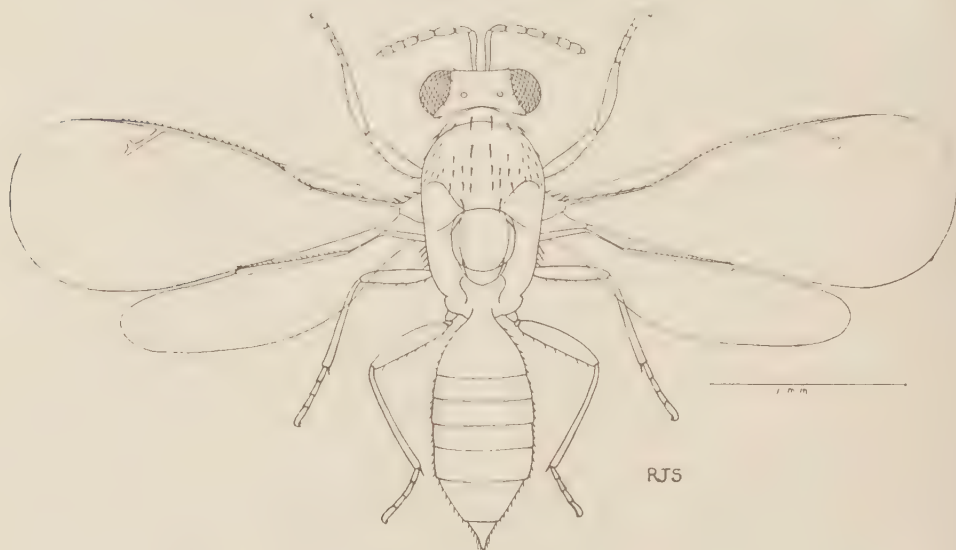


Fig. 13. *Eulophus metalarus*, female.

Dicladocerus westwoodi (fig. 12, *a*, *b* & *c*) is known from North and Middle Europe, having been recorded from Britain, Sweden, and Lapland. In addition to specimens from the Forest of Dean we have obtained it from Alpes Maritimes, France. It was apparently absent from Cambridgeshire. No previous host records are known, but there are specimens in the British Museum reared from *C. laricella* at Bagshot, Surrey, in June 1920, and named by Waterston. The adult insects commenced emergence early in May and were observable till the end of September. It was nowhere very abundant. Rearings from a lot of 1,750 case-bearer larvae from the Forest of Dean yielded a parasitism of 2·9 per cent.

The eggs are laid on the young larva within its case, the latter being pierced by the ovipositor. No certain character has been found for distinguishing the first-stage larva of *Dicladocerus* from that of *Eulophus* (*q.v.*). The mature larva possesses nine pairs of open spiracles, and the shape of the mandibles (fig. 12, *c*) serves to distinguish it from that of the third-stage larva of *Chrysocharis*. By this means the cast skins can readily be separated.

Eulophus metalarus (figs. 13, 14, 15) was reared in small numbers from *Coleophora* larvae collected at Wilbraham, Cambridgeshire, in the winter of 1930–31, but was obtained nowhere else. It was emerging in the insectary from the 9th to the 20th



Fig. 14. *E. metalarus*: a, antenna of ♂; b, antenna of ♀.

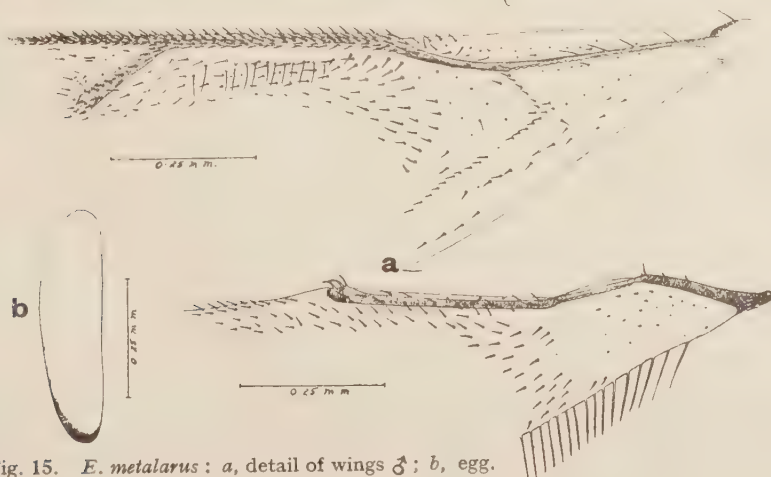


Fig. 15. *E. metalarus*: a, detail of wings ♂; b, egg.

May, the ratio of males to females being nearly 3:1. A number of individuals, supplied with sugar and water, were kept alive in a "lamp-glass cage" for 60 days. It is an external parasite and is, so far as our limited experience goes, a primary. The first-stage larva (figs. 16, 17) has four pairs of open spiracles and the head structures and mouth-parts (fig. 17) are somewhat similar to those described for *Melittobia* (see Parker, 1924). There are no previous host records.

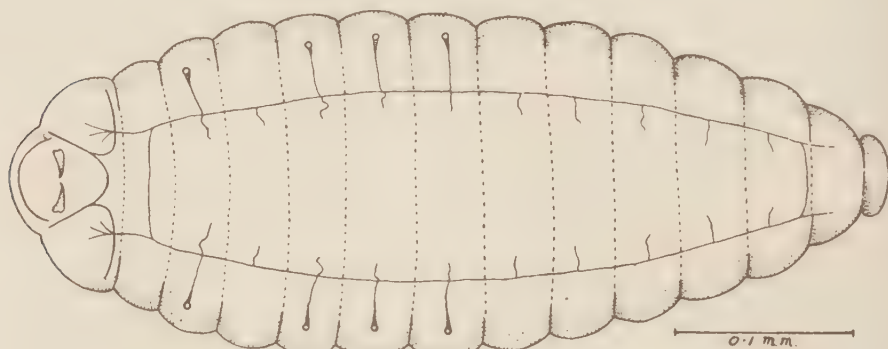


Fig. 16. *E. metalarus*, first-stage larva.

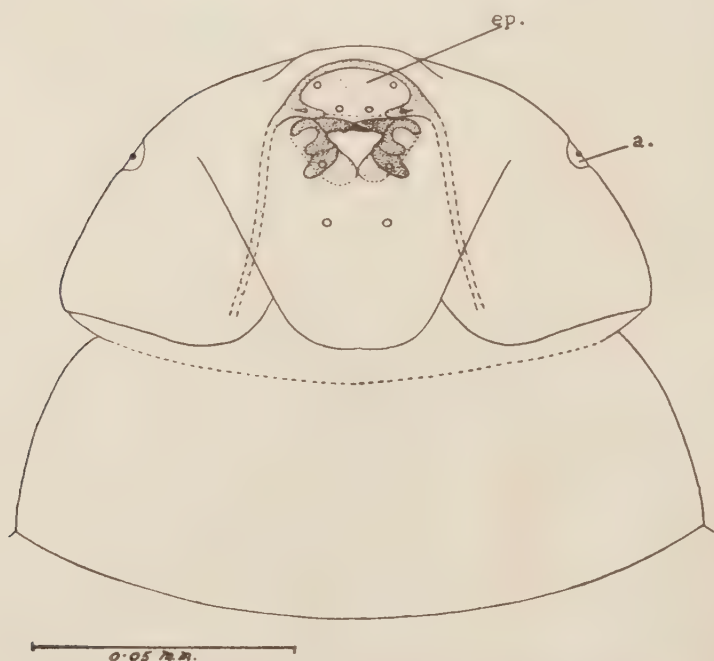


Fig. 17. *E. metalarus*, first-stage larva. Ventral view of mouth-parts and head structures: *a*, antenna; *ep*, epipharyngeal region.

Two species of BRACONIDAE were obtained from the case-bearer. The most important of these is *Microdus pumilus*, Rtz., an insect already recorded from *C. laricella*, which is its only known host. We have reared material from St. Martin

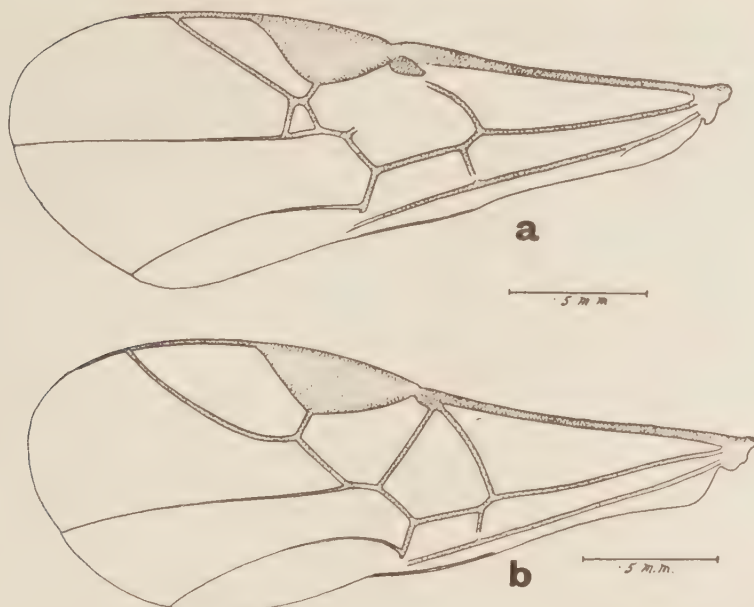


Fig. 18. Wing venation of *a*, *Microdus pumilus*, ♀; *b*, *Sigalphus caudatus*, ♀.

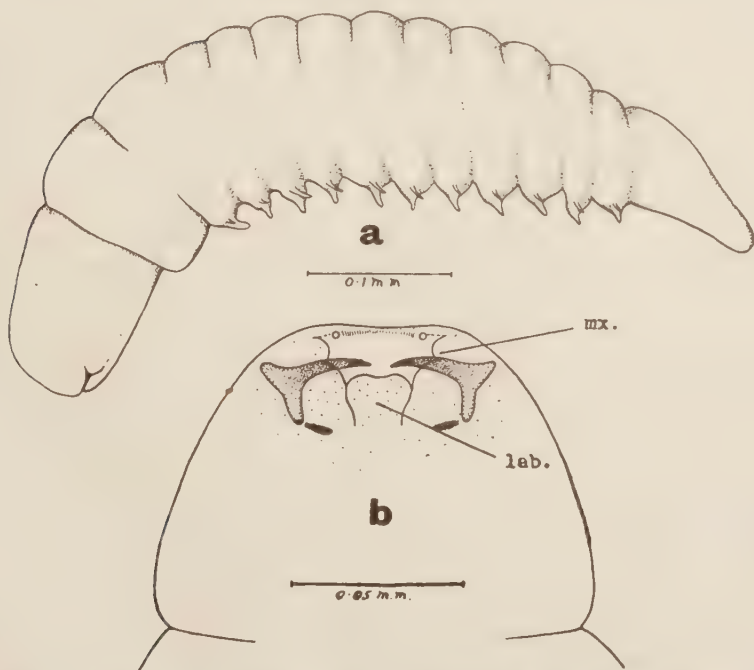


Fig. 19. *M. pumilus*: *a*, first-stage larva; *b*, first-stage larva, ventral view of mouthparts and head structures; *mx.*, maxillary region; *lab.*, labial region.

de Vesubie, A.M., France, and from Cinderford, Forest of Dean, Gloucestershire. Hitherto this species has been known only from Germany.

M. pumilus, an Agathidine, is a somewhat slender, mainly black insect with smoky wings, a finely rugose metanotum and a short stout ovipositor. The only other *laricella* parasite likely to be confused with it is *Sigalphus caudatus*, Nees, which is a stouter species, brilliant shining black, with pale wings, a long slender ovipositor, and the metanotum smooth and shining. The wing venation (fig. 18, *a, b*) is quite different in the two species. The only other Braconid recorded is *Bracon guttiger*, a species with black and yellow abdomen and the apparently circular mouth-opening characteristic of the division Cyclostomes to which it belongs.

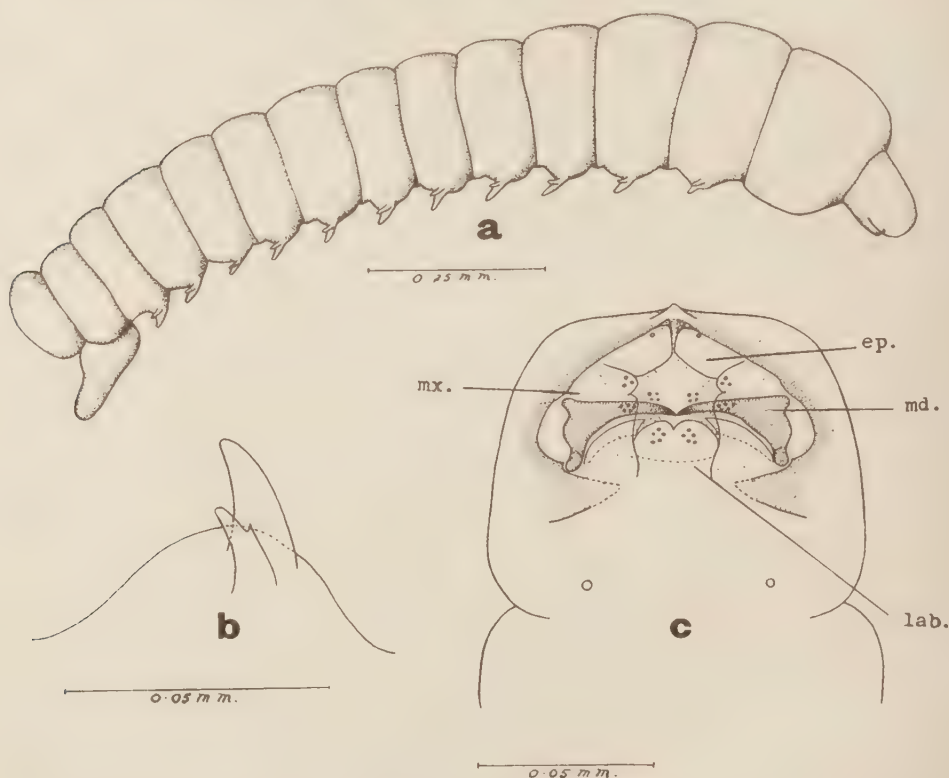


Fig. 20. *M. pumilus*: *a*, second-stage larva; *b*, second-stage larva, detailed structure of an abdominal appendage; *c*, second stage larva, ventral view of mouth-parts and head structures; *ep.*, epipharyngeal region; *lab.*, labial region; *mx.*, maxillary region; *md.*, mandible.

Microdus pumilus was found to be very rare in England. It was obtained only from Cinderford in the Forest of Dean, three specimens being reared. It was, however, abundant in the material from the South of France where a parasitism of 12 per cent. was recorded. Adults commenced emergence on 21st June. It is an internal larval parasite, passing the winter as a first-stage larva and is, in all probability, single-brooded.

The first stage is a polypod larva of a remarkable type (fig. 19, *a*), similar to that described in *Microdus dimidiator*, Nees, by Silvestri (1923) but at present unknown elsewhere among the BRACONIDAE. While the head (fig. 19, *b*) is that of a typical Braconid the presence of a pair of double appendages on each body segment except

the first (fig. 20) recalls the primary larvae of certain PROCTOTRUPIDAE. *M. pumilus* appears to differ from *M. dimidiator* in that even in the first instar the tracheal system may be partly visible owing to contained gas, and also in that the abdominal appendages persist until the second instar. In *M. dimidiator* moreover a single pair of appendages is described on the second and third post-cephalic segments and two pairs on each of the following nine, whereas typically in *M. pumilus* one finds four appendages (*i.e.*, one double pair) on each segment after the first. This varies however in different individuals and I have found some specimens in which segments 2 and 3 each bore a single pair and others in which they lacked them altogether. The first segment always lacks appendages in both species. A rudimentary anal vesicle is present in the second instar of *M. pumilus* (fig. 20, *a, b, c*). Unfortunately I have been unable to obtain further material of *Coleophora* from the French locality and consequently have had no opportunity of describing the later larval stages.

A number of specimens of the other Braconid, *Sigalphus caudatus*, was obtained from a consignment of infested larch twigs collected at Wilbraham, Cambridge, in December 1930. The parasite had presumably come from *C. laricella*. A year previously dissection of material from this locality showed approximately 3 per cent. parasitism by a distinctive first-stage Braconid larva which was found nowhere else. Although we failed to rear this form, it seems highly probable that it was the larva of *S. caudatus*.

Sigalphus caudatus is found throughout Europe, having been recorded from England, Germany, Russia, France, and Italy. It has a surprisingly varied host list, including Lepidoptera, Coleoptera, and Diptera. In view of this it should perhaps be mentioned that the larch trees from which our specimens were obtained were heavily infested with the Anobiid beetle, *Dryophilus pusillus*, Gyll., and possibly this species also serves as a host.

The following insects are on record as hosts of *S. caudatus* :—

Lepidoptera.—HYLOPHILIDAE : *Hylophila bicolorana*, Fuessl. LASIOCAMPIDAE : *Dendrolimus pini*, L. TORTRICIDAE : *Semasia* (*Tortrix*, *Lathronympha*) *hypericana*, Hb. TINEIDAE : *Carcina* (*Halias*) *quercana*, F., *Tischeria complanella*, Hb.

Coleoptera.—ANOBIIDAE : *Ochina hederac*, Mull. (*ptinoides*, Marsh.). CURCULIONIDAE : *Byctiscus betuleti*, F. (*betulae*, L.), *B. populi*, L., *Orchestes fagi*, L., *O. quercus*, L. (?). SCOLYTIDAE : *Thamnurgus euphorbiae*, Kust.

Diptera.—OSCINIDAE : *Oscinella frit*, L.

No parasites were found attacking the eggs of *C. laricella*, nor are there any egg parasites recorded in the literature.

5. Notes on the Rarer Species.

Of the remaining species in the list but little can be said as practically nothing is known of their biology. *Cirrospilus pictus*, Nees, with its two varieties *arcuatus*, Först., and *immaculatus*, Thoms., was reared in some numbers from case-bearer larvae collected at St. Martin de Vesubie, A. M., France. In this locality the type form was much less abundant than either of the varieties and males were more than twice as common as females. In England *C. pictus* was found to be very rare, the only form present being var. *immaculatus*, of which we have two males from Cambridgeshire and a female from the Forest of Dean. This form has not hitherto been recorded from Great Britain.

Habrocytus sp. is represented by three males, two from St. Martin de Vesubie and one from Wilbraham, Cambs. Of *Eupelmus* sp. a single male was obtained from Wilbraham.

Three specimens of *Eurydinota laricinellae* were obtained ; a male and female from Wilbraham and a single male from St. Martin de Vesubie.

6. The Encouragement of Indigenous Parasites.

Malenotti (1924) has considered the possibility of increasing the efficiency of the indigenous parasites of the case-bearer by artificial means. He suggested that branches of larch, heavily infested with parasitised case-bearers, should be placed in wooden boxes covered with gauze of a mesh such that the emerging parasites would be able to escape while the moths would be retained. He was dealing with the small Chalcids, *Chrysocharis laricinellae* and *Cirrospilus arcuatus*, only; with the larger species such as *Angitia* and *Microdus* the host and parasite are so nearly of the same size that it is hardly likely that the method would be feasible.

Malenotti himself shows, however, that under the conditions prevailing in North Italy, where his experiments were carried out, there is little hope of it ever proving a practical proposition. His reasoning is as follows: The annual production of wood from a larch plantation is valued at 270 lire a hectare and it is estimated that a heavy infestation of *Coleophora* reduces this yield by about half. The boxes used are 50 cm. by 70 cm. by 70 cm.—0.245 cubic metres capacity. The cost of one of these boxes, made on the spot, works out at 19 lire. The labour required to fill each box and place it in position is reckoned to cost 2 lire, making a total of 21 lire a box. Thus, at the outset, to place out 6 boxes on a hectare would cost 126 lire, a sum very nearly equal to that lost through *Coleophora* attack. At the best one can only get about two-thirds of the most heavily infested foliage from one tree into a box and this would not amount to as much as one-hundredth of that remaining on the other trees. Even supposing, then, that the boxes could be produced in quantity at a lower figure and that they could be used for several years and the cost thus spread over a considerable period, it seems unlikely that the method would be of any practical value. If the boxes could be used for five years, which seems unlikely, and the initial cost reduced to 15 lire, the annual cost of placing out the boxes would be reduced to 5 lire. Then about 25 boxes could be placed instead of 6; even so, the proportion of infested foliage that could be accommodated within them would still be less than one-twentieth and it is improbable that this would be sufficient to produce any appreciable difference.

7. Predators.

No insect predators were actually observed to attack case-bearer larvae. The nymphs of the red Capsid bug, *Capsus ruber*, are often common on larch infested with case-bearer. Some of these bugs were caged on larch shoots bearing the eggs of *Coleophora* but no definite evidence that they feed on them was obtained. One was observed, however, to thrust its proboscis repeatedly into an empty *Coleophora* case and it is quite likely that a certain number may be destroyed in this way. The present writer has previously shown (Petherbridge & Thorpe, 1928) that this species is both carnivorous and phytophagous.

Three other species of CAPSIDAE were found fairly commonly on infested larch trees in the Forest of Dean. *Calocoris sexguttatus*, Fabr., is a polyphagous species which is, under certain conditions, liable to be carnivorous (Butler, p. 404). Nothing is known as to the feeding habits of the other two species; *Atractotomus magnicornis*, Fall., is recorded from various conifers; *Psallus luridus*, Reut., is confined to young larches.

Birds are undoubtedly of great value in reducing case-bearers. Most important in this respect are the Tits (*Parus* spp.). In addition, the Chaffinch (*Fringilla caelebs*, L.), the Willow Warbler (*Phylloscopus trochilus*, L.), the Yellow Hammer (*Emberiza citrinella*, L.), the Golden-crested Wren (*Regulus regulus*, L.), the Nuthatch (*Sitta europaea*, L.), and the Garden Warbler (*Sylvia simplex*, Latham) among other Warblers, may be mentioned.

In Canada, Baird (1923) has recorded the following birds as particularly valuable: Song Sparrow (*Melospiza melodia*, L.), Chipping Sparrow (*Spizella passerina*, L.),

Mourning Warbler (*Oporornis philadelphia*, L.), and Goldfinch (*Astragalinus tristis*, L.). He estimates that in places 75 per cent. of the case-bearers were destroyed by birds, but that over a larger area 25 per cent. would be a fair average figure.

8. Other controlling Factors.

It is quite evident that various environmental factors other than parasites and predators, play a very important part in determining the abundance of *Coleophora laricella*. In the first place, as has already been mentioned, young trees are more liable to attack than older ones. Again, damp, rainy weather, and particularly heavy rains during the flight period, causes the destruction of great numbers of the moth. Escherich states that dry and sunny slopes are most sought out by the moth; in other words, it prefers those places in which larch trees may be expected to do best. This was borne out by my own experience in the Forest of Dean in 1930. Thus the heaviest infestation was found in a plantation of trees of 11 years of age, growing at an altitude of 750 feet above sea-level; the soil being a light loam derived from coal measures; that is, growing under decidedly favourable conditions. Again, in a different part of the Forest a fairly heavy infestation was seen on trees of 30 years of age, growing on a light loam at an altitude of 500 feet. A striking contrast to this was seen in two other plantations. In the first of these the trees were 9 years of age, the soil clay or, at best, a heavy loam, and the whole area low-lying and decidedly susceptible to frost. *Coleophora* attack was very slight. In the other area the trees were 20 years old, but owing to unfavourable conditions were unhealthy and deformed by frost and canker. The soil was a heavy clay and the whole area swampy and very susceptible to frost. *Coleophora* was practically non-existent in this plantation. While one must not give too much weight to isolated observations such as these, they are of interest in that they support the statement of Escherich, quoted above, that the moth prefers dry sunny localities.

There are, however, some apparently contradictory observations on record. Thus some observers state that attack is likely to be more severe in seasons and in localities in which there are sudden temperature changes and particularly where late frosts occur. This may well be due to the fact that while moths are usually less abundant in such areas the damage caused is proportionately greater owing to the injurious effects of such conditions on the trees and the consequent decreased vitality. Boden (1902) records a case where all the unhealthy sickly larches in a plantation were attacked and had sustained severe injury, while the sound sturdy plants had suffered much less. Whether the better condition of the sturdy plants was due to a milder infestation or to a greater recuperative power on the part of the victim does not appear.

According to Fankhauser (1908), in mountainous country the moth is very much more destructive in the lower districts than it is at higher altitudes. This is presumably because, in the lower areas, while the whorls of young needles make their appearance earlier in the spring their rate of development is very slow and consequently the larva finds time to destroy a greater number of needles than in the higher districts, where the development, although commencing late, takes place exceedingly rapidly.

But much remains to be done before we have any really clear idea of the factors governing the intensity of case-bearer attack. The incidence of local attack very often appears extremely capricious. Thus one may find two trees of the same age growing side by side on the same soil and apparently under identical environmental conditions. One will be severely attacked, while the other is practically free. At present there seems to be no explanation to offer for such differences.

Again, according to Malenotti, a case-bearer attack in a given area usually lasts three years, after which it need no longer be regarded as serious. Whether such fluctuations are due to the influence of parasites or to some other factors we do not know.

9. Shipment of *Angitia* to Canada.

When it was decided to undertake the introduction of *A. nana* into Canada an attempt was made to breed it in pure culture. Eight potted larch trees were placed in a compartment of a large outdoor insectary and a large number of moths were liberated in the compartment as they emerged from cut shoots of infested larch stored in "emergence cages." In this way freedom from any other parasites was ensured. Numerous males and females of *Angitia nana* were then liberated in the insectary in the same way, and the process of parasitism was allowed to take its course. Some difficulty was experienced, in that the moths did not breed as readily in the insectary as had been hoped and the somewhat artificial conditions are liable to affect the developmental periods of parasite and host somewhat differently, with the result that the life-history of the former is no longer exactly synchronized with that of the host, as it is in nature. Nevertheless, in spite of these difficulties the experiment was moderately successful and over 500 larvae were obtained for shipment in the following summer, the degree of parasitism by *Angitia* being in the neighbourhood of 60 per cent. Since this material alone was not sufficient for the purposes of shipment, early in June 1931, collections of case-bearer larvae were made in a part of the Forest of Dean where a high degree of parasitism (60 per cent.) by *Angitia* had been observed previously. Two shipments, consisting of 10,310 and 11,100 case-bearer larvae obtained in this way, were despatched to Canada on 16th and 26th June 1931, respectively: care being taken that only *Angitia* was liberated in the latter country. I am informed by Mr. Baird that the material unfortunately arrived in Canada during a prolonged spell of extremely hot weather, the shade temperature running as high as 106° F. This was no doubt responsible for the very great mortality which evidently occurred before arrangements could be made for the proper cooling of the cages. Mr. Baird tells me that as a result not more than 103 specimens of *Angitia* emerged and of these only 20 females were liberated. Belleville, Ont. was the locality chosen for liberation. No recoveries of the species have yet been recorded.

10. Summary and Acknowledgments.

This paper consists of a preliminary report on investigations of the parasites of *Coleophora laricella* in Europe, with a view to their possible utilisation in Canada.

Systematic and biological notes on the more important species are given.

The most promising parasite, *Angitia nana*, has already been shipped to Canada. It is a solitary internal parasite of the case-bearer larva. Further investigations are necessary before it can be considered safe to introduce any other species.

I am very grateful to Dr. C. Ferrière, of the Imperial Institute of Entomology, for the time and trouble he has given to the work of identifying the parasite material. The late Mr. J. C. Robbins helped materially by kindly carrying on observations while I was absent through illness, and by collecting material in the field. Mr. R. J. Spittle has been of great assistance in the production of the finished drawings, several of them being mainly his own work. A number of the earlier field collections were made by Mr. H. S. Hanson.

11. Appendix.

SYSTEMATIC NOTES ON THE CHALCIDOIDEA.

By Dr. CH. FERRIÈRE.

Among the parasites of *Coleophora laricella* bred at Farnham House Laboratory were seven species of Chalcidoidea:—

EUPELMIDAE: *Eupelmus* sp. PTEROMALIDAE: *Habrocytus* sp., *Eurydinota laricinellae*, Ratz. EULOPHIDAE: *Cirrospilus pictus*, Nees, *Eulophus metalarus*, Walk., *Dicladocerus westwoodi*, Steph., *Chrysocharis laricinellae*, Ratz.

Of the two unnamed species, of which only single males were found, not much can be said. We can only mention that species belonging to these genera have been already bred from *Coleophora*. De Gaulle (1908) gives three species of *Eupelmus*—*urozonus*, Dalm., *vesicularis*, Wesm., and *annulatus*, Nees—as parasites upon different species of *Coleophora*; *Habrocytus fasciatus*, Thoms., has been obtained from *C. acrisella* in France (Suire, 1927); De Gaulle and Suire also mention *Pteromalus variabilis*, Ratz., as a parasite of *C. giraudi* and *C. mongetella*. For the four other species, the following systematic notes may be of interest.

Eurydinota laricinellae, Ratz.

The specimens examined agree exactly with the description of *Pteromalus laricinellae*, Ratz., which was bred in Germany from the same host. But the abdomen in both males and females is distinctly, if shortly, petiolate (the petiole being about as long as broad), and the species belongs therefore to the genus *Eurydinota*, Först., of the SPHEGIGASTERINAE. It seems to differ from *E. leptoneura*, Först., the other European species, mainly by the colour of the legs. Another species *E. lividicorpus*, Girault, is known in North America as a parasite of *Coleophora malivorella*.

Cirrospilus pictus, Nees.

Among the several specimens bred from *C. laricella* were different forms which we considered at first as different species. But by closer examination of all the specimens, we were unable to find good morphological characters to separate them. The differences lie in the variable extent of the clear markings on the thorax and legs, and even here a sharp separation is not always possible. It seems that all the specimens belong to one species only, which must be called *C. pictus*, Nees, but that they can be separated into varieties as shown by the following key:—

1. Legs entirely clear yellow, with only a black ring on the middle tibiae. Thorax with a broad transverse stripe at end of mesonotum, and the tegulae yellow *pictus*, Nees, typ. form.
 Legs with femora and tibiae more or less dark. Thorax with smaller or no yellow markings 2
2. Mesonotum with a narrow stripe or two yellow spots before the scutellum; basal half of median and hind femora and a spot or line on the fore and median tibiae black var. *arcuatus*, Först.
 Mesonotum without yellow spots, except under the base of wings; median and hind tibiae more broadly black in the middle var. *immaculatus*, Thoms.

The males, especially of the last two varieties, are difficult to separate.

Eulophus metalarus, Walker.

This insect is distinguished from the many other species of the genus by the brown cloud on the forewings of the female, just below the stigmal vein; the greenish head and thorax; the more or less purple-reddish of the scutellum and to a lesser extent of the mesonotum; and by the dark legs, which have the femora greenish and the knees and metatarsi yellowish. The antennae (fig. 14) have a three-jointed funicle and a three-jointed club; the first funicle joint elongate, the second shorter, a little longer than broad, the third still shorter and subquadrate, also shorter than the club. The males are smaller, greenish, with hyaline wings and three long branches on the antennae.

Walker's description must have been made from several specimens, both males and females, from the Isle of Wight and from Ireland, since he mentions seven different colour variations. In the collections of the British Museum there are only

three females; two from England and one from Clermont, France. They differ from the above bred specimens only in having the cloud on the wing a little darker and the metatarsi more distinctly whitish.

There are no previous host records for *E. metalarus*, but *Eulophus magnisulcatus* Girault, has been bred from *Coleophora* sp. in North America.

Dicladocerus westwoodi, Steph.

This species is easily distinguished from the species of *Eulophus* by the presence on the male antennae (fig. 12, *a*) of only two long branches, on the first and second funicle joints. The female (fig. 12, *b*) has a three-jointed funicle and a three-jointed club; the first funicle joint is elongate, longer than the pedicel, the joints two and three are much shorter, subquadrate. The body is green, the antennae black except the scape of the male which is yellowish, the legs are dark with the knees and tarsi clear yellow; in the male the front tibiae and half the median and hind tibiae are also pale.

Chrysocharis laricinellae, Ratz.

The specimens, whether bred in England or in France, agree exactly with the description given by Ratzeburg, and although there are some slight variations in coloration, especially on the legs, we are not able to separate them into forms or varieties.

Wolff (1916) has given a key to the European species, but he distinguishes two groups, one with white tarsi, in which are all Thomson's species, the other with dark tarsi containing Förster's species. All the species known to me have clear tarsi, and it seems certain that the author did not see the species of Förster. Ratzeburg's species, described under *Entedon*, are not included in this key, which is therefore of but little help. A monographic study of this genus will certainly reveal many synonymies among the numerous species included. *C. laricinellae*, Ratz. (fig. 7), is characterised by its bluish-green colour, its short antennae, in which the funicle joints are not much longer than broad, the third being subquadrate, the dark scape, and the legs in which only the end of the femora, the tibiae and the tarsi are clear yellow; sometimes the tibiae are more or less darkened along the outside.

The following key may help to distinguish the genera of the parasites of *C. laricella* mentioned above:—

1. Antennae with 13 joints, the funicle with 6 or 7 joints; tarsi with 5 joints 2
 Antennae with fewer joints, only 2 or 3 in the funicle; tarsi with 4 joints 5
2. Middle tibiae with a strong spur; funicle with 7 joints ... *Eupelmus*
 Middle tibiae without strong spur; funicle with 6 joints ... 3
3. Abdomen short oval, petiolate; funicle joints short ... *Eurydinota*
 Abdomen generally more or less elongate, not petiolate; funicle joints longer 4
4. Abdomen oval; first funicle joint of female not or little longer than the pedicel
 Pteromalus
 Abdomen elongate, pointed and carinate below; first funicle joint longer
 than the pedicel ... *Habrocytus*
5. Funicle with two joints; scutellum with two longitudinal furrows
 Cirrospilus
 Funicle with three joints; scutellum without furrows ... 6
6. Submarginal nerve in forewing broken before it bends to the marginal nerve;
 stigmal nerve very short, but the post-marginal nerve not much longer
 Chrysocharis

Submarginal nerve not broken ; stigmal nerve longer, the post-marginal nerve twice as long as the stigmal 7

7. Antennae of male with three branches on the three first funicle joints, the fourth joint the longest *Eulophus*

Antennae of male with two branches ; the third funicle joint longer than the fourth *Dicladocerus*

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OBSERVATIONS ON *GLOSSINA MORSITANS*, WESTW., IN EAST AFRICA.By W. H. POTTS, M.A. (Cantab.), *W**Department of Tsetse Research, Tanganyika Territory.***Introduction.**

The object of these investigations was to examine the effect of temperature on *Glossina morsitans*. The work has so far been done in the main on the pupal stage only. This has entailed the production of pupae of known age in the laboratory, and the testing of the viability of puparia collected from natural breeding sites. I propose in this preliminary account to give only a summary of the results obtained. In these discussions the words "pupae," "puparia," "flies" and "tsetse-flies" will be understood to refer only to *Glossina morsitans*, Westw., unless specifically stated otherwise.

The work has been done under the Department of Tsetse Research, Tanganyika Territory, at Kikori (4°21' S., 35°19' E.), situated at an elevation of 4,062 feet, on the western edge of the Masai Steppe. I am grateful to Mr. C. F. M. Swynnerton, Director of the Department, for permission to publish these results. I wish also to express my indebtedness to Mr. J. Y. Moggridge, also of this Department, for assistance with the routine of observations entailed by the work. Finally, I am glad of this opportunity to thank Professor D. Keilin, of the Molteno Institute of Parasitology, Cambridge, and Mr. F. A. Potts, of the Department of Zoology, Cambridge, for reading the manuscript and for suggesting improvements thereto.

The puparia used in the experiments were those deposited in the Laboratory, or collected from natural breeding sites either near Kikori or at Sambala, situated in a neighbouring fly-belt at a distance of some 50 miles to the south-west of Kikori. The conditions obtaining in the Kikori fly-belt have been described by Nash (1930, pp. 201-204); those in Sambala, by Jackson (1930, pp. 495-498).

The Production of Pupae in the Laboratory.

I made preliminary attempts in this direction during a period of three months. As a result of these, a routine was established and carried out by Mr. J. Y. Moggridge during the subsequent four and a half months. A description of this routine follows.

Adult flies, captured near the laboratory, were kept in receptacles of capacity 500 and 1,500 cc., 5 to 10 flies in each. The smaller receptacles were glass beakers of the type commonly used in chemical experiments, closed at the top by mosquito netting. The larger were glass lamp-chimneys, closed at the top by mosquito netting, and at the bottom by cheese cloth, a closer meshed material, which was found necessary because the larvae were able to escape through tightly stretched mosquito netting. The breeding vessels were kept inside the laboratory, the temperature of which did not vary very greatly. The usual daily variation was about 10°F. or slightly less; the maximal and minimal temperatures during the period were 82°F. and 59°F. respectively. The relative humidity ranged from 40% to 90%, the usual daily variation being about 10-20%; no attempt was made to increase the humidity in the breeding vessels, even at the driest times.

The flies were given the opportunity of feeding once a day, on cattle or on goats. Just before the feed, each receptacle was examined and the dead flies removed, recorded, and replaced by recently captured ones, females by females, and males by males. At the same time the larvae or resultant pupae deposited since the previous

examination were removed and recorded. In this way the numbers of flies in each receptacle were kept constant throughout the experiment, and a high mortality amongst the females did not necessarily cause a reduction in the numbers of larvae deposited.

The preliminary experiments showed that unless the numbers were kept constant in the manner described, the increase in separate breeding vessels necessary to keep up the numbers of pupae produced would have been inconveniently large, and the working up of the results too complicated. It is realised, however, that the procedure had disadvantages, mainly because it involved regarding a changing population as a constant factor. Thus, for example, were female mortality influenced by larviposition (*i.e.*, suppose that the chances of a female dying are higher during larviposition) then a high female mortality might coincide with a greater production of larvae.

The effects were tested of varying the proportions of the sexes, of clipping the wings, and of shading the receptacles, and a comparison was made of the results of feeding on cattle and on goats. The following points emerged :—

(a) Puparia were produced with comparative ease under the above conditions. The actual figures were : (1) maintenance of a stock of 85 females on cattle blood for 2 months (May and June) needed the replacement of 123 females (*i.e.*, about 2 a day), and produced 121 pupae ; (2) maintenance of a stock of 120 females for 2 months (July and August) needed the replacement of 227 females (*i.e.*, about 4 a day) and yielded 145 pupae.

(b) There was a suggestion that cattle blood was more suitable than that of goats, as the female mortality was significantly higher amongst the flies fed on this blood, although the numbers of larvae produced were not significantly different.

(c) Clipping of the wings made no difference, either to the female mortality, or to the production of larvae ; it was a definite advantage, in that it minimised loss of flies when the mosquito net coverings of the receptacles were accidentally displaced.

(d) It appeared that better results were obtained by keeping 5 females with 3 males, than by keeping 5 females with an occasional male, in that the female mortality was significantly lower in the first instance, although the numbers of larvae produced remained unchanged. Later experiments, though not giving numbers large enough to be conclusive, suggested that equality of sexes (5 ♀♀ & 5 ♂♂) did not give such good results as did the proportions 5 ♀♀ to 3 ♂♂.

(e) Neither shading of the receptacles, nor their nature (*i.e.*, whether beakers or lamp-chimneys) made any significant difference to the female mortality, or to the numbers of larvae produced.

It is interesting to note that the number of larvae produced by one female during May was nearly double that produced during any subsequent month. This agrees with observations in the field during 1929–30 to the effect that the greatest proportion of pregnant females were caught in April, and the two facts together suggest that there may be an increase in breeding activity at this time of year.

Observations on Puparia produced in the Laboratory.

Larviposition and Pupation.—Larviposition generally occurred during the late afternoon or night. Of the 515 normal-sized larvae deposited only 40 (7·7%) failed to pupate. These puparia were slightly smaller and lighter than those collected from natural breeding-sites.

The white larva may move actively by peristaltic contractions for as long as an hour after deposition, at least when placed on a hard surface. When, however, placed on sand, it burrows almost immediately, becoming rigid and motionless within a quarter of an hour of burrowing. Then very soon the white becomes tinged with

yellow, deepening through chestnut to black, and the puparial skin becomes increasingly hard and chitinated. The time needed for the completion of this process seems to vary. Thus, although generally the puparium appears black and fully chitinated within 15 to 17 hours, there would sometimes be a slight tinge of chestnut still visible after this time. Exceptionally the whole process was completed in so short a time as 8 hours. Generally the puparium becomes quite hard and black within 18 hours of deposition.

Emergence.—Out of 302 puparia, 262 (86·8%) emerged. The numbers of males and females resulting were exactly equal.

Pupal Period.—The average duration was 45·9 days. The males took slightly longer to complete their pupal period than did the females, their average period being 47·2 days, as compared with 43·0. This agrees with some observations by Lloyd (1913, p. 286) working with the same species in Northern Rhodesia.

The pupal period varied with the temperature :—

12th Feb. to 5th May	30·9 days mean noon temperature	77·3°F.
1st April to 11th June	38·4 " " " "	73·7°F.
1st May to 30th July	47·8 " " " "	71·5°F.
1st June to 18th August	48·5 " " " "	70·0°F.
1st July to 21st September	45·3 " " " "	71·2°F.

Data are available for working out more closely this relation, and it is hoped to publish these later.

A temperature of 30°C. (86°F.) lowered the mean pupal period (19 pupae) to 23·1 days, but it also increased the mortality to 26·3% (nearly double). At 35°C. (95°F.), all pupae were found to be dead after 13 days.

Stages of Pupal Development.—Pupal development may be divided into four stages, each of which occupies roughly a quarter of the total period. These are :—

(a) From the appearance of a typical Dipterous larva, until three body regions are distinguishable, during which time the pupal contents are very watery, and their colour blue-white ; (b) thence until all the appendages and form of the imago are apparent, but pigment has not yet appeared, the contents of the pupa being no longer so watery, and their colour creamy white ; (c) from the time pigment first becomes apparent as a pale orange tint in the eye, until the body hairs also become pigmented, although the general colour is still creamy white ; (d) thence to the formation of the perfect imago inside the puparium.

Fiske (1920, p. 412) recorded stages of pupal development on similar lines, based on an examination of pupae of *G. palpalis* collected from natural sites.

Observations on Puparia collected from Natural Breeding Sites.

Effect of Laboratory Conditions on Emergence.—In two series of puparia collected from natural breeding-sites and kept untreated in the laboratory as controls, the percentages of emergence were 70·4 and 59·9, the totals being 523 and 152 respectively. The percentage naturally alive, as revealed by examination shortly after collection, was even lower—45·6% in a series of 423 puparia, and 49·1% in another of 1,173 puparia. On the other hand, the percentage emergence in puparia deposited in the laboratory was as high as 86·8 (see above). It would therefore appear :—(a) That in a collection of puparia from natural breeding-sites over half the total may at times be dead at the moment of collection. There is some evidence that this may vary with the season, as was also suggested by Chorley (1929, p. 291) in Southern Rhodesia ; (b) that transfer from natural conditions to the laboratory does not interfere appreciably with emergence from the puparia, but that a little over 10% may be expected to die in the course of development.

Parasitisation.—One species of Hymenopterous parasite, and three species of Bombyliid (Diptera) parasites were bred from tsetse puparia. The former (*Syntomosphyrum glossinae*, Waterst.) was scarce; e.g., in a series of 2,185 puparia, 4 only were parasitised (i.e., less than 0.2%). The Bombyliids were more numerous, e.g., of 2,724 puparia, 6.2% were parasitised. This proportion varied in different series from 2.2% (total pupae 680) to 9.9% (total 423). This variation, whilst perhaps due in part to situation, as some breeding-sites were more heavily parasitised than others, is probably mainly due to seasonal fluctuations, for the different series were collected at different periods of the year.

The three species of Bombyliids were *Thyridanthrax abruptus*, Lw. (the most common), *T. lineus*, Lw., and *T. argentifrons*, Aust. The first two species have previously been recorded as widely distributed over East Africa, the last only from the West Coast (Austen, 1929, pp. 156, 158, 162). I have to thank Major Austen for confirming my identifications of these species.

Viability Tests.—As a preliminary to any experimental work with puparia collected from natural breeding-sites, it was imperative to find some test of their viability which did not involve breaking them open. At first, the difference in weight of dead and living pupae was tested. Later, at the suggestion of Dr. J. F. V. Phillips, a method used by seed-testers was tried, namely, that of buoyancy in liquids. Both were found to be successful, but as the buoyancy tests took much less time, they were adopted. The liquids used were petrol and methylated spirits, as they had to be lighter than water, in which nearly all puparia, whether dead or alive, floated. The results of these tests may be summarised thus:—

(1) The average weight of the live puparium was just over double that of the dead one—296 mg. as opposed to 132 mg. (424 puparia).

(2) The weights of puparia parasitised by Bombyliids were so near those of the normal ones, as to allow no means of distinguishing the one from the other.

(3) Immersion in petrol and methylated spirit did not interfere appreciably with emergence: e.g., in some series, of 448 puparia immersed, 56.9% emerged, as opposed to 59.9% out of the 152 controls; similarly, in a second series, of 680 puparia immersed 69.4% emerged, as compared with 70.4% out of 523 controls.

(4) The results of the immersion tests, when the puparia were examined immediately, may be summarised thus:—

In 50% methylated spirit (S.G. 0.925)—of 177 puparia sinking, 100% were alive, but so also were 40% of the 996 which floated.

In 25% methylated spirit (S.G. 0.900)—of 309 puparia sinking, 100% were alive, but so also were 31% of 864 which floated.

In undiluted methylated spirit (S.G. 0.820)—of 561 puparia sinking, 97% were alive, as were only 5.2% of 612 which floated.

In petrol (S.G. 0.740)—of 663 puparia sinking, 86.3% were alive, and only 0.8% of the 510 which floated.

Thus, if only those puparia sinking in methylated spirit of S.G. 0.820 were taken, nearly all would be alive at the time of the test, and so fit subjects for experiment. By using diluted methylated spirit, all sinking puparia would be alive, but a third or more of those rejected would also have been alive.

In a further series of tests, in which emergence was awaited, similar results were obtained, but the percentages of emergences were lower than those of the living by about 15 to 20%. This discrepancy is greater than the percentage emergence of puparia deposited in the laboratory would have led one to expect, and as a matter of practice, when the experiment necessitated awaiting emergence, only those sinking in methylated spirit of S.G. 0.900 were selected, although this meant that nearly a third of the puparia rejected might have emerged. This also had the advantage of rejecting most of the parasitised puparia.

(5) Of those puparia which floated in petrol, 95 to 100% proved to be dead.

(6) Of the puparia which sank in methylated spirit, 1 to 2½% only were parasitised; of those which floated in petrol, only 0 to 5% were parasitised. It is obvious then that most of the parasitised puparia floated in methylated spirit, but did not do so in petrol. If then the living are eliminated by removal of those sinking in methylated spirit, and the dead by removal of those floating in petrol, the remaining fraction, *i.e.*, those that float in methylated spirit, but sink in petrol, will consist mainly of parasitised puparia. Actually a number of parasitised puparia will be missed in this way; *e.g.*, of 169 parasitised puparia:—

1	sank in methylated spirit of	S.G. 0.925 (0.6%).
1	" " " "	S.G. 0.900 (0.6%).
36	" " " "	S.G. 0.820 (21.3%).
101	sunk in petrol of ...	S.G. 0.740 (59.8%).
30	floated in petrol of ...	S.G. 0.740 (17.7%).

So, if the main purpose of the test is the selection of the parasitised puparia, it will be best to retain all floating in methylated spirit, although a large proportion will be dead.

(7) The dilutions of methylated spirit were originally tried in the hope that they would separate the early from the late pupal stages. As was apparent both from puparia examined at the time of the test, and from those left to emerge, they failed to do so.

(8) In conclusion, the living, dead, and parasitised puparia may be separated from a miscellaneous collection, by immersion first in methylated spirit, and removal of those that sink, which may be considered to be alive, and then immersion in petrol of those that floated, when the puparia sinking may be considered as parasitised, and those floating as dead.

Effect of Heat on Pupae.

The following are conclusions drawn from a number of experiments, the details of which it is not possible to give in a short account of this nature. The numbers on which they are based are not very large, and the conclusions must be regarded as tentative, and needing further confirmation.

Puparia exposed in batches of 10 to temperatures gradually changing by 10° and 5°C., etc.

(a) Puparia did not withstand exposure for 15 minutes to temperatures above 50°C. (122°F.); (b) puparia were able to survive, for 30 minutes, exposure to 40–45°C. but not for 30 minutes to 45–50°C., *i.e.*, the lethal temperature for a 30-minute exposure probably lies between 45 and 50°C; (c) puparia survived exposure for 5 minutes to 45–50°C., and probably for 15 minutes; to 50–55°C. for 5 minutes but not for 15 minutes, and to 55–57°C. for 2 minutes,* but not for 5 minutes.

Thus whilst puparia can survive an exposure of 2 minutes to 55–57°C.,* the lethal temperature for exposures of 5 minutes lies between these two temperatures, for exposures of 15 minutes, between 50 and 55°C.; further 30 minutes at 45–50°C. may be lethal, whereas 40–45°C. is not lethal, even for one hour.

Puparia kept constantly at 40°C., or alternating between that and Room Temperature (about 20°C.).

(a) Puparia seemed able to withstand an exposure of as long as 8 hours to 40°C., but one of 24 hours appeared injurious; (b) two days exposure to 30°C. appeared to

* It is probable that in this short time, the living tissues of the pupae did not reach 55–57°C.; before such figures can be accepted, information is needed as to the time taken by the internal tissues of the pupae to attain the temperature of their environment.

have no ill effect, but longer exposures may increase the percentage mortality (see p. 295); (c) puparia withstood 40°C. for 4 hours, for 8 hours doubtfully, and for 24–25 hours not at all (100% mortality in three batches of 10), and also successfully withstood 8 hours exposure to 40°C. in two periods of 2 hours each, and one of 4 hours (at 24 hour intervals), and also 12 hours, in three periods of 4 hours each; (d) puparia were doubtfully able to resist 3½ hours at 40°C., probably unable to resist 4 and 6 hours, and certainly not 8, 10, or 12 hours; also certainly not 4 hours repeated twice; (e) exposures of 2 hours, repeated 5 times, were probably not injurious.

The results from this series seem a little contradictory, but they suggest that puparia are unable to withstand 40°C. for much over 4 hours, but that they can withstand longer periods than this, even up to 12 to 10 hours, if the exposure is administered in daily doses of 2 hours, or possibly even of 4 hours.

Puparia kept constantly and continuously at 30 and 35°C.

(a) There is a suggestion that 30°C., whilst not lethal, may raise the percentage mortality (40% as opposed to 10% in the controls), the probability of these figures being obtained by chance being between 1 in 10 and 1 in 20; (b) Nineteen puparia kept at 30°C. (86°F.), showed a mortality of only 26·3%, but the puparial period was definitely decreased (to 23·1 days); the controls showed only about 13% mortality, and a pupal period of 45·5 days (at room temperature, which varied from 66–75°F., the monthly mean minimum and maximum); (c) thirteen puparia kept at 35°C. (95°F.) were all found to be dead in 13 days.

Thus pupae can complete their development at 30°C., with possibly a slightly higher mortality, but in a shorter time than at lower temperatures. They cannot, however, complete their development at 35°C.

Puparia exposed to 0°C.

(a) After 24 hours exposure to 0°C., 66% (total 55) emerged as compared with 84% (total 44) of the controls; the controls were treated exactly as the experimental puparia, except that they were not exposed to 0°C., and the difference is perhaps not highly significant (it would occur by chance between 1 in 10 and 1 in 20 times); (b) after exposure of 1 hour to 0°C., 96% emerged (total 52), as opposed to 89% of the controls (total 46); (c) after 1½ hours exposure to 0°C., 97% emerged (total 59), as opposed to 96% of the controls (58).

Effect of Immersion and Occlusion of the Respiratory Lobes.

(1) Burial of puparia in sand saturated with water, or covering them entirely with shellac, proved fatal (100% mortality).

(2) Occlusion of the respiratory lobes alone, with shellac, was not fatal, nor was the application of a similar patch of shellac to the anterior end.

(3) Immersion in water was not harmful, but may have delayed emergence; e.g., of the controls, 4 emerged, and 6 remained unhatched but alive during the experiment, lasting 10 days; none of the experimental ones emerged, 15 remaining unhatched but alive. The probability of this occurring by chance is between 1 in 20 and 1 in 50.

Effect on Adult Flies of Exposure to 0°C.

Adult tsetse recovered from exposures to 0°C. of 3 and 12 hours respectively. It is possible that such exposures may cause a decreased ability to digest food, but it

was not possible to test this adequately. This was suggested by the fact that a number of the dead flies were found to have undigested blood in their alimentary canals.

Effect on Adult Flies of Exposure to 40°C.

Adult flies seemed able to survive short exposures to 40°C. (104°F.) even if repeated a number of times. While not able to withstand continuous exposures of an hour, they did survive as much as three to five hours, provided that the exposures were broken at intervals of from 5 minutes to half an hour. I was unable to ascertain the humidity conditions obtaining during these experiments, exposure to heat being effected by means of a thermostated water oven. It did not appear to make any difference whether the flies were contained in a mosquito net container or in a glass specimen tube, closed at the top with mosquito net.

Summary.

1. Methods used in the production of pupae of *G. morsitans*, Westw., in the laboratory have been described.

2. Observations, based on the pupae produced in the laboratory, have been recorded on larviposition, pupation, pupal period and stages of pupal development.

3. The pupal period was found to vary with the temperature, from 23.1 days when kept constantly at 86°F., to 48.5 days at a varying temperature, the mean noon temperature during development being 70.0°F.

4. Examination of puparia collected from natural breeding-sites showed that there is a fairly heavy mortality in the pupal stages in nature, amounting in some cases to as much as 50%.

5. Parasitisation by the Hymenopterous parasite, *Syntomosphyrum glossinae*, was found to a very slight degree—0.2% only.

6. Heavier parasitisation by three species of Bombyliids—*Thyridanthrax abruptus*, *T. lineus*, and *T. argentifrons*—occurred.

7. The living, dead, and parasitised puparia could be distinguished by (a) immersion in methylated spirit of S.G. 0.820, when those sinking would be alive, and (b) subsequent immersion in petrol of those floating in methylated spirit, when those sinking would for the greater part be parasitised and those floating would be dead.

8. The degree of temperature lethal to pupae was found to depend on duration of exposure. Thus, whereas pupae survived exposure to 55–57°C. for 2 minutes,* 45–50°C. was lethal when the exposure lasted half an hour, whilst even 40°C. was lethal when continued for 4 hours or more, and pupae failed to survive 13 days at 35°C.

9. Exposure to 0°C. for as long as 24 hours may increase the mortality of pupae, but for 1 to 1½ hours certainly did not do so. Adults recovered from similar exposures of 3 and 12 hours duration, although their ability to digest blood may have been impaired.

10. Whilst the total exclusion of air from puparia proved fatal, occlusion of the so-called respiratory lobes did not. Immersion in water was not harmful, but may have delayed emergence.

11. Adult flies survived short exposures to 40°C., even when repeated a number of times, but not continuous exposure of as much as one hour.

* See note on p. 297.

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THE BIONOMICS AND CONTROL OF *DYSDERCUS* (HEMIPTERA) IN THE SUDAN.

B. M.

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(PLATES VII-X.)

Introduction.

One of the most important pests of rain-grown cotton in the Sudan is the genus *Dysdercus* (PYRRHOCORIDAE) of the Hemiptera Heteroptera. Upon the introduction of cotton into the southern provinces of the Sudan, these insects appeared in great numbers, and in certain districts threatened to render impossible the growing of the crop. In 1926 work was started on the bionomics and control of the cotton-stainers by Cowland & Ruttledge, who were working respectively in the Nuba Mountains and the Fung provinces. Later the crop in the Nuba Mountains proving to be the more important of the two, the study of these insects was confined to that region. Mr. Ruttledge followed Mr. Cowland as entomologist in the Nuba Mountains, and the writer followed Mr. Ruttledge in 1928. The results of the preliminary investigations of Cowland & Ruttledge¹ formed a valuable base from which the writer continued the work.

Distribution.

The genus *Dysdercus* is, so far as the writer knows, present in every cotton-growing country in the world with the exception of Egypt, Mesopotamia, Turkestan and the Northern portion of the American cotton belt. In the Sudan it occurs generally south of the 14th parallel, north of this it has only been found at Zeidab and Tokar. Occasional specimens have been taken elsewhere but they were accidental visitors and were not breeding. The distribution of the genus in the Sudan is dependent upon several closely interconnected factors, but it may be safely stated that rainfall is the most important of these. The rain-belt in the Sudan, as will be seen on referring to Plates vii-x, may be divided into two portions. The more northerly belt stretches roughly from the 20th parallel to the 13th parallel and has an annual rainfall of from 25 mm. in the north to 400 mm. in the south. The southern belt stretches from the 13th parallel in the north to the southern boundary of the Sudan or approximately the 4th parallel, its rainfall ranging from 600 mm. to 1,200 mm. per annum. The following species occur in the Sudan, and reference to the accompanying maps will show their relative distributions: *Dysdercus supersticiosus*, F., *D. fasciatus*, Sign., *D. nigrofasciatus*, St., and *D. cardinalis*, Gerst.

Economic Importance.

The damage done by these insects to cotton is considerable and is of two types, primary and secondary. The former is caused by the action of the bug's salivary secretion and by the adult excreta staining the lint. The latter embraces all bacterial and fungous boll-rot resultant upon organisms entering the unopened boll through the punctures made by the bug's stylets. In the former category the damage caused by the salivary juices varies with the age of the boll; the bugs do not appear to attack the very young bolls; but they do not wait, as has been stated by some writers, until the bolls are open. They seem to make their first attack at about the half-grown stage, when the boll is approximately a little over half an inch in diameter.

At this stage the bug's salivary secretion almost invariably has a harmful effect upon the developing seed, which is still soft, the result usually being that the seed tissues break down and either degenerate into a slimy mass, or that the seed stops growing, becomes shrivelled, and eventually it and the boll dry up. It would appear that the latter condition is common amongst the more mature bolls. The damage caused by the excreta of the adult bug is confined to opened bolls, the excreta of all stages of nymphs is colourless, but that of the adults is of a dirty yellow colour, and when a number of adults are clustered on an open boll feeding upon the seeds, they usually discolour the lint with their excreta.

Secondary damage is of an entirely different nature, and is by far the commoner of the two, being in fact the main feature of stainer attack on cotton. Both fungi and bacteria enter the bolls through the stylet punctures, giving rise to a variety of diseases almost all of which completely destroy the bolls. The symptoms of such attack vary from a slimy wet rot similar to that caused by the salivary secretion of the bug, to a dry rot which completely eats out the interior of the boll. No work has been done upon this aspect of the question in the Sudan, but there is no reason to suppose that the harmful fungi and bacteria differ greatly from those described by Nowell.^{2,3,4}

The most commonly noticed symptom of the presence of stainers, other than their appearance in large numbers in the cotton, is the yellowing of the lint in the opened bolls. The gravity of stainer infestation is very seldom appreciated until this yellowing becomes apparent, and it is insufficiently realised that, in addition to lint discoloration, most of the wet boll rot, and a large part of the dry boll rot, in Southern Sudan cotton is directly attributable to stainers.

Life-histories.

Before describing the life-histories of the various species it is important to note that the terms food-supply and host-plant have a special significance as used here. As will be seen later, in the case of every species a number of plants are capable of sustaining the bug's life, but only certain plants, in each case, are able to furnish the wherewithal by means of which the bugs can breed. Therefore the term host-plant indicates those plants on which the bugs can breed, while food-supply embraces all plants that at one time or another, during the year, provide food and moisture to the bugs, but which are of insufficient food value to allow of breeding.

Dysdercus cardinalis, Gerst.

This species is only found towards the far south of the Sudan, and little is known of its history. The only host-plant other than cotton on which it has been found is *Sterculia cinerea*, A. Rich. It is relatively scarcer than the other species of *Dysdercus*.

Dysdercus nigrofasciatus, St.

So far as is known the life-cycle of this species is identical with that of *D. supersticiosus*, with the exception that it has never been found upon *Sterculia*; it is rather less abundant than the latter species.

Dysdercus supersticiosus, F.

While the life-cycle of this species (fig. 1) is probably the same wherever it occurs in the Sudan, the following description is based on observations made in Mongalla Province. Eggs are laid in the surface soil. There are five nymphal instars, the lengths of which vary slightly according to food-plants and climatic conditions, the average life-history being as follows:—Egg-laying to incubation, six and a-half days; 1st instar, three days; 2nd instar, four days; 3rd instar, five days; 4th instar, six days; and the 5th instar, eight days. The bug has a number of wild host-plants, of which the most permanent would seem to be various herbaceous Malvaceae (*Hibiscus Wissadula*, etc.). At the end of the rains in October, the bugs spread from these wild

host-plants on to cotton, which is then maturing bolls, and thence to *Sterculia cinerea*, on which the fruits are ripening. During November and December the bugs multiply rapidly on the seeds of *S. cinerea* and cotton, but tend to leave the latter towards the end of December and return to *Sterculia* and the various Malvaceous weeds which are growing in damp situations; they persist on cotton here and there where the habitat is sufficiently damp to enable the plant to remain green.



Fig. 1. Life-history of *Dysdercus supersticiosus*, F.

In March and April the bugs are very scarce and can only be found on *Sterculia* and Malvaceous weeds in exceptionally favourable situations, and more rarely on cotton that has not been cut out and has also enjoyed favourable conditions, while occasionally they can be found on a small shrub, *Dombeya kirkii*, which is fruiting at this time of the year. In the drier localities the bugs have not been found during these months. In May the early rains have stimulated fresh growth in the herbaceous Malvaceae, thus providing food for the bugs, which seem to desert *Sterculia* at this point. No observations have been made between May and October, but it is conjectured that the bugs continue breeding on the herbaceous Malvaceae, again reaching cotton in October.

Reference to the circular diagram (fig. 1) illustrating the life-history of *D. supersticiosus* will show the important parts played by climate and host-plants, and the relatively long breeding season afforded the bug by the wide choice of the latter. The inner thick line represents the period of active breeding, which extends from the beginning of May until the end of February, the other less thick lines represent the periods in the life-histories of the various host-plants, during which the bugs are feeding and breeding upon them. Following the diagram round clockwise, *i.e.*, following the calendar, we see that the climatic conditions are only adverse to the bug during the short period between the beginning of March and the beginning of April, and that even during this short time there are occasional rains, and the humidity is sufficiently high to enable the insect to hold its own in many localities. The wide range of host-plants also affords it suitable food-material at all periods during the year.

Dysdercus fasciatus, Sign.

This species is confined to the northern portion of the rain-belt in the Sudan. The length of the life-history (fig. 2) depends upon the conditions of temperature and humidity, and to a certain extent upon the amount of food available. Eggs are laid in the surface soil from about a quarter to half an inch deep. If conditions be favourable they hatch in about seven days. There are five nymphal instars and these vary in length, the average time being about two days in the first, six in the second, five in the third and fourth, and seven in the fifth instars. The average time from egg to adult is just over a month under favourable conditions. The adults start to copulate almost immediately after attaining maturity, and in a very short time a large colony is formed. The natural host-plant is the tebelidi or baobab, *Adansonia digitata*, the fallen seeds of which furnish the sole means other than cotton by which the bugs can exist in the Nuba Mountains. After a short time under favourable conditions the bugs tend to cluster and congregate into colonies, which increase in size until the trunks of the tebeldis are red with the insects. After a colony has formed upon the trunk of one of these trees, if the rate of breeding is maintained, a large number of adults will sooner or later migrate, either in small scattered bands, singly, or in pairs, by which means the species is spread and multiplied. The bug can only feed upon the fallen tebelidi seed, as the fruit itself offers an impenetrable barrier to its stylets, and it is only when the latter has fallen and has either been broken open by the fall, or eaten by white ants that the seeds become available to the bugs. This results, however, in a constant supply of food, as unless they are swept up and collected, there is always a quantity of fallen fruit and seed scattered around the trunks of the larger trees.

Under reasonably favourable conditions breeding continues throughout the year, but slows up during the dry season; the drier the season the slower the breeding rate becomes. The Nuba Mountains are normally too dry for any of the other species of *Dysdercus*, and even in the case of *D. fasciatus*, during the period from the end of February to the middle of June, existence is extremely precarious, for even under favourable conditions breeding goes on very slowly, and the bug does not get away properly until the end of June.

During the cotton-growing season large numbers of bugs leave the tebeldis and in their search for fresh breeding-grounds frequently come across cotton cultivations, where they settle and colonise. Here they stay until either the cotton is cut out, or until the lack of moisture drives them off the rapidly drying plants; in either case they can only return to the tebeldis. The tebeldis grow to a very large size, and the bark on the older ones is much corrugated and folded; there are also frequent fissures leading into the hollow centres of the trunks. Such trees form ideal hot weather resting-places, and the bugs hide in them and slowly continue breeding. In dry years only the most suitable of these tebeldis will be able to afford sufficient shelter for the bugs.

Normally all cotton should be cut out and burnt about the end of March or beginning of April, and therefore the only source of food supply is the fallen tebeldi seed; frequently, however, isolated cotton areas are forgotten by their native owners, and the bugs manage to exist on such plants as remain green. Heaped up cotton seed



- * All stages common. —————
 fairly common. - - - - -
 scarce.
 * Adults common & clustering. —————
 common & flighting. ————
 scarce in cotton & flighting back to tebeldis. ————
- Tebeldi seed. —————
 Cotton seed. —————
 Cultivated & native cotton. ————

Fig. 2. Life-history of *Dysdercus fasciatus*, Sign.

and other debris, which the cultivators have tidily collected and swept up under some shady tree or bush, frequently affords an ideal breeding-place for the bug. It will be seen on reference to fig. 2 that the only apparent controlling factor is climate; the lack of rain from December to February and virtually March, and the high

*These lines should be of the same thickness.

temperature and low humidity from January to the end of April not only restrict the northward trend of the other species of *Dysdercus*, but also act as considerable checks upon *D. fasciatus*.

Ecology.

The study of any insect from an economic point of view invariably involves the study of its ecology to a greater or less extent. In the case of *Dysdercus* the study of the bug's ecology is all-important. Two factors, climate and food-plants, are of extreme importance in the control of members of the genus in the Sudan. The two in conjunction are almost the sole limiting factors of the distribution of the various species.

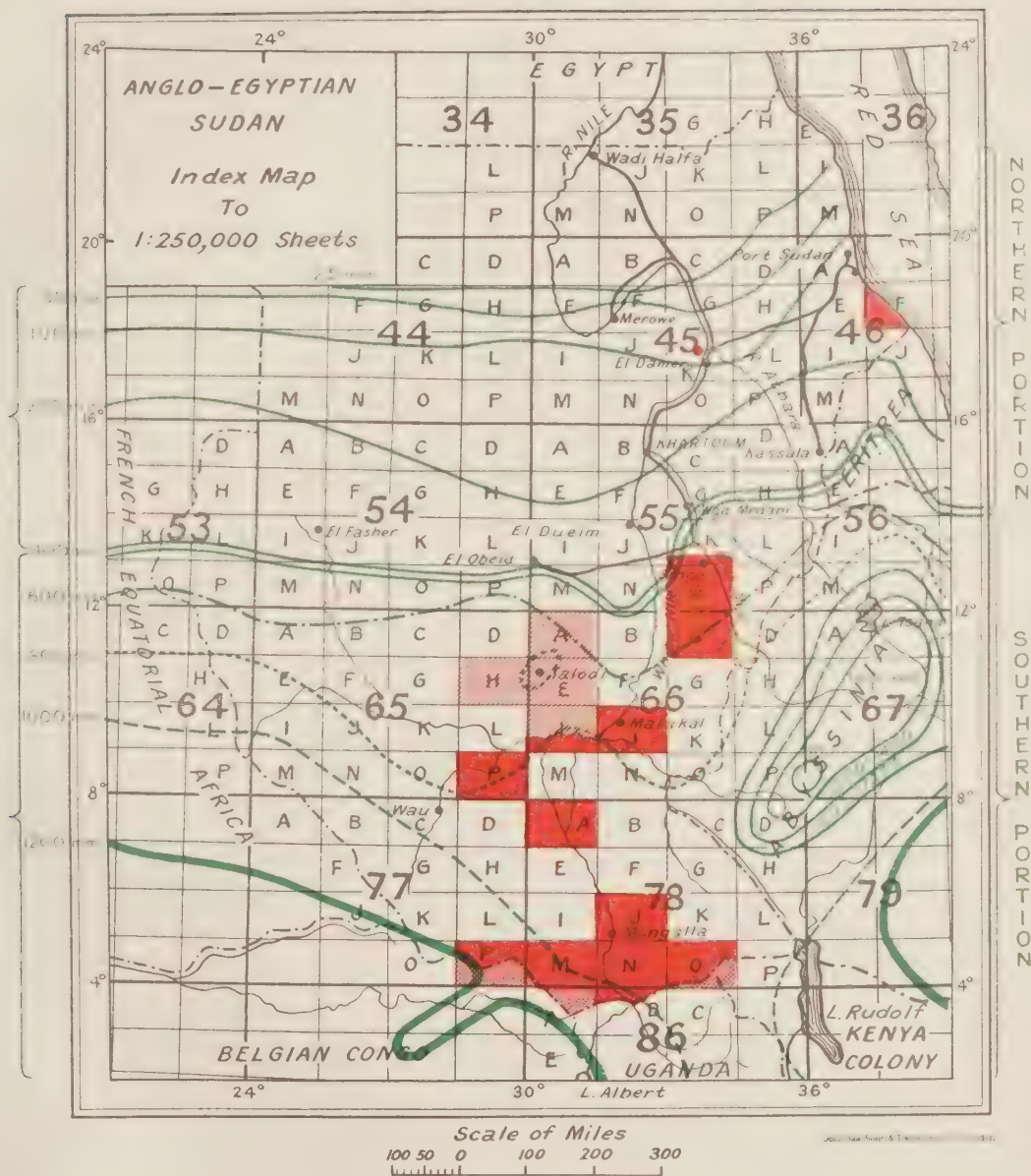
The rain-belt of the Sudan (Plates vii-x), as has already been stated, may be roughly divided into two portions. The northern with a maximum annual average of about 400 mm. and the southern with a maximum annual average of about 600 mm. at its northern extremity but increasingly steadily to 1,200 mm. at the far south. The following tables represent the meteorological data obtained during the last few years from the Nuba Mountains and Mongalla Province. The circular life-history diagrams of *D. fasciatus* and *D. supersticiosus* are based on these figures.

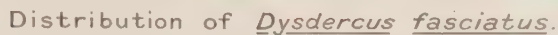
Aggregate Averages from various Stations in Mongalla Province.

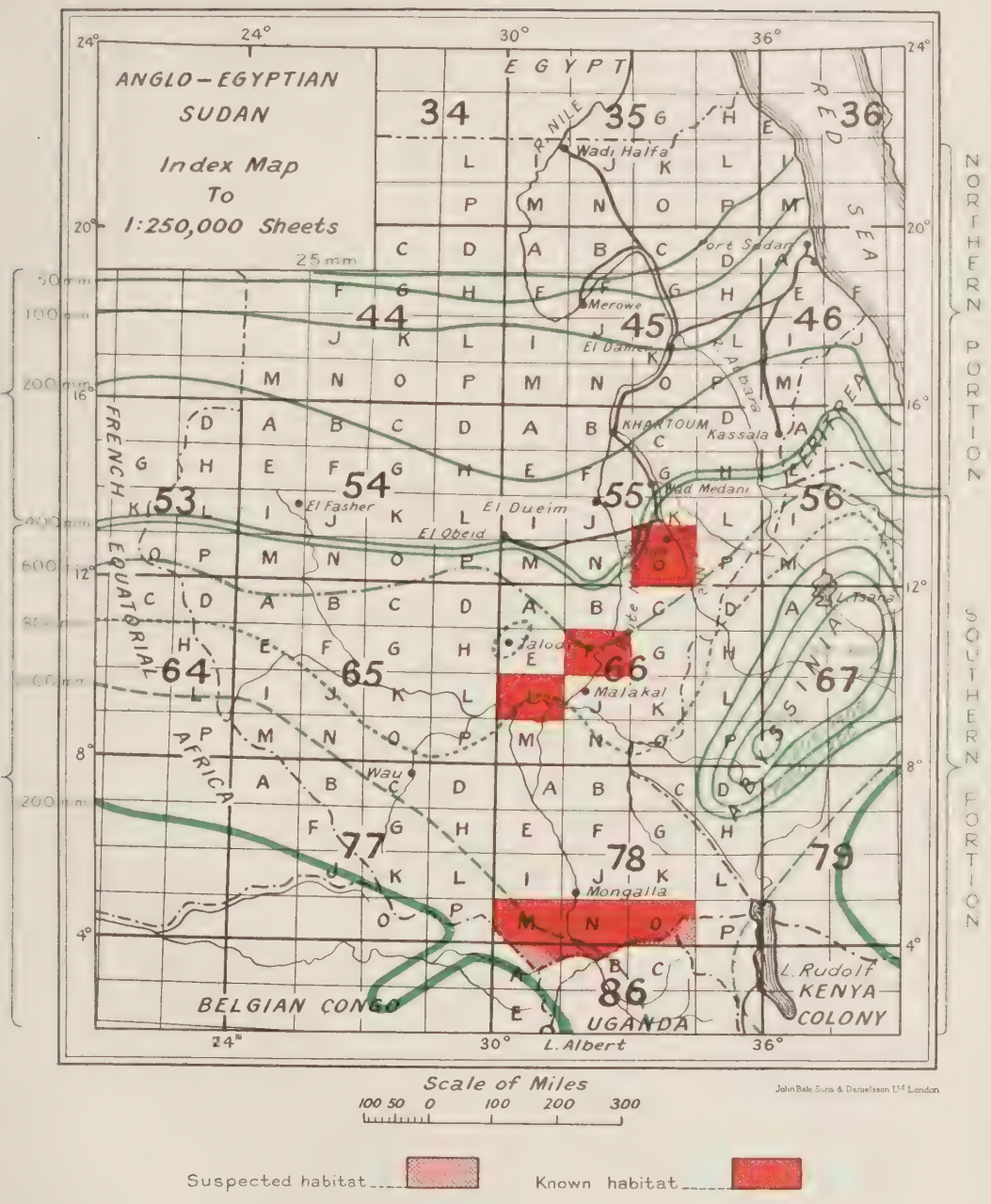
Month	Rainfall in mm.	Temperature (F.)	Humidity %
January ...	5.5	91.0	—
February ...	23.2	95.0	61
March ...	68.7	91.4	63
April ...	144.0	89.2	71
May ...	172.0	85.6	—
June ...	131.9	82.0	78
July ...	142.6	81.7	86
August ...	154.6	82.0	87
September ...	144.4	84.0	83
October ...	143.7	84.0	76
November ...	89.9	88.0	73
December ...	16.5	90.0	—
Annual Totals	1,237.0	1,043.9	

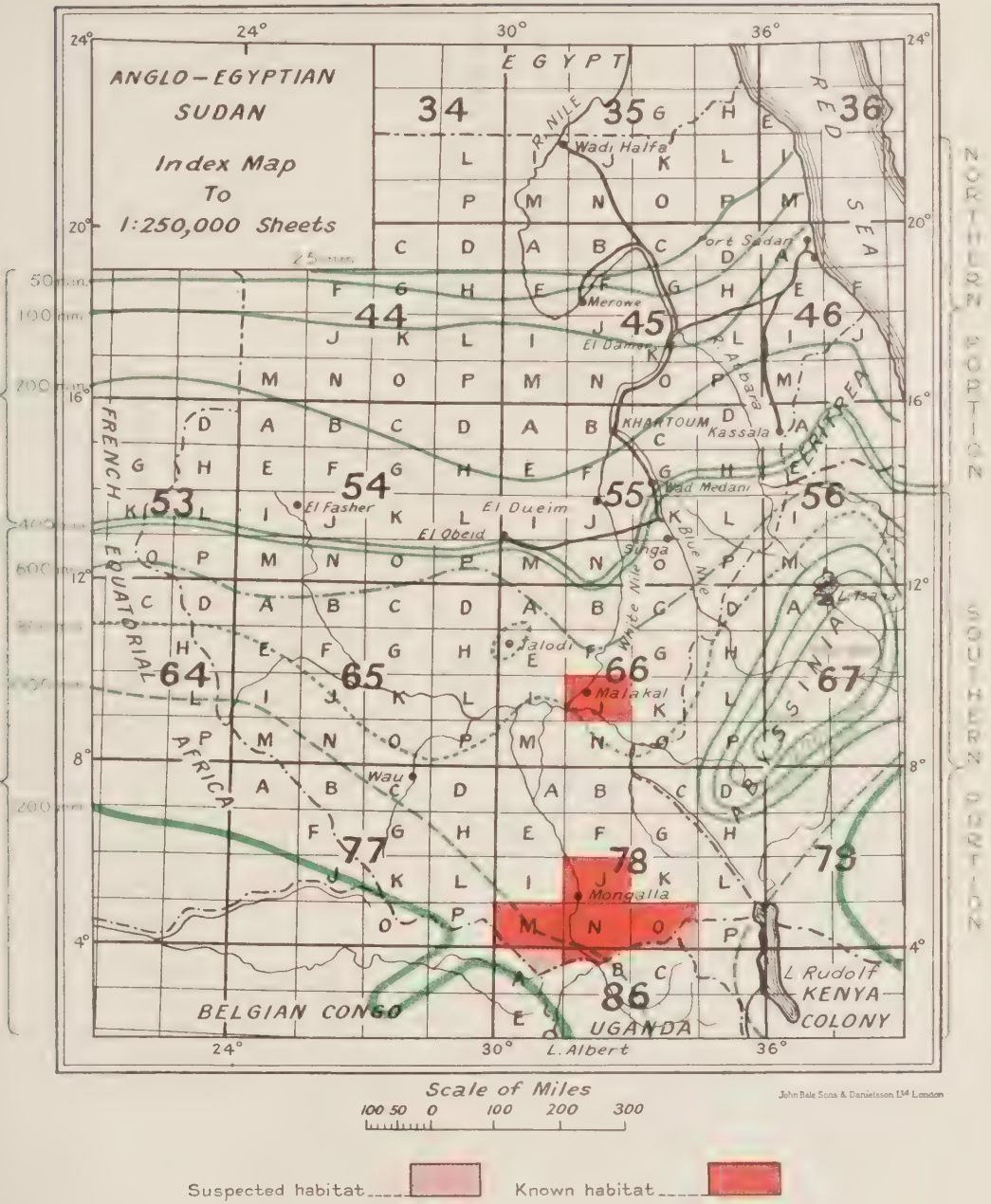
The figures above are from various stations. The rainfall figures are averages from Kajo Kaji, Nimule, and Yei over the period 1919-1929. The temperature figures are average maximum shade temperatures from Meridi during 1930. The humidity figures are less reliable than the others owing to the fact that few records have been kept, they represent a fairly correct average, however, and are comparable with those of the Nuba Mountains.

The genus *Dysdercus*, may, in the Sudan, be divided into two sections, *D. fasciatus* inhabiting the northern and drier portion of the rain-belt, and the remaining three species inhabiting the southern and rainier portion. There are, of course, overlappings, but in the main these divisions are accurate enough for a line to be drawn where the two approach one another. The northern trend of *D. supersticiosus*, *D. nigro-fasciatus*, and *D. cardinalis* is undoubtedly limited almost entirely by climate. Their









METEOROLOGICAL DATA, NUBA MOUNTAINS.
1930-1931. (Rainfall from 1925.)

MONTH	RAINFALL MM.										°F TEMPERATURE						% HUMIDITY																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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*The final monthly average figures have been computed from Talodi and Kadugli, as both centres are representative of the general climate of the Nuba Mountains. It is unfortunate that the temperature and humidity records do not go back any further than 1930. It may be taken, however, that the present figures are representative of the normal climate in the Nuba Mountains, the rainfall figures illustrating the general uniformity over the last eight years.

**These are monthly averages from Talodi and Kadugli of the *maximum* shade temperature.

host-plants are mostly distributed throughout the southern Sudan, but the climate of the Nuba Mountains and the northern portion of the Fung Province is unquestionably too dry for them. In the case of *D. fasciatus*, however, the factor of host-plants is relatively more important, for this species can not only breed in much drier climate than can the other three, but it can also exist in the more humid conditions preferred by the latter. The fact that it is restricted to the Nuba Mountains and the Fung Province requires more explanation than climatic conditions can afford, the inhibiting factor being the restricted range of wild host-plants. As has been mentioned, the only food-supply other than cotton is the tebeldi tree; this tree does not occur south of Tonga for a considerable distance, and in this absence lies the explanation of the limited habitat of *D. fasciatus*. Field experiments and observations have proved conclusively that the bug is unable to breed on any available food-plants other than cotton and the tebeldi.

Not only are climate and food-plants the main factors affecting distribution, but climate is also the main factor affecting reproduction and development. The southern portion of the rain-belt is undoubtedly more favourable for all species of *Dysdercus* on account of the higher general humidity and the longer period in which rain occurs during the year. The further we go north, the longer the dry season and the more difficult it becomes for the bugs to carry on through it. An important feature of the bug's life-history is that there is no true resting period; during the dry season the rate of reproduction slows down considerably, the bugs are less active and tend to cluster in cracks and folds of the bark of the tebedis, but breeding does not cease except with the death of the bug, a fact which renders the insect far more vulnerable to drought and heat than would otherwise be the case. The foregoing is an established fact in the case of *D. fasciatus*, but detailed information has not yet been obtained in the case of *D. supersticiosus*, *nigrofasciatus* and *cardinalis*.

Put briefly the facts are as follows: The species of *Dysdercus* found in the Sudan do not have a true resting period, adverse conditions merely inhibiting reproduction and even destroying them. The inhibiting factors are climate and food-supply. In the southern rain-belt the dry season is shorter and of a higher humidity than in the northern portion, therefore the bugs are affected less by climate and more by the range of host-plants. *D. fasciatus* is only prevented from flourishing in this area by the lack of its only wild host-plant. In the northern belt, particularly in the Nuba Mountains, *D. nigrofasciatus* and *D. cardinalis* are almost certainly excluded by climate, the dry season being too long and severe for them; *D. supersticiosus*, which has a more northerly limit than the other two, occurs periodically in the Nuba Mountains, but only in extremely favourable years, and since 1928 only three specimens have been taken from this area; here again it is the long and severe dry season which is the controlling factor. *D. fasciatus* can undoubtedly stand a higher temperature and a lower humidity than can the other three species, but in dry years it dwindles in numbers until it is only found in attenuated clusters in the more favourable situations.

The northern limit of all species, with the exception of special localities such as Zeidab and Tokar, where irrigation alters conditions, appears to be about a line drawn through El Obeid and just south of Sennar. North of this a Pentatomid bug, *Agonoscelis versicolor*, F., occurs, whose habit of resting for a period of nearly nine months during the year enables it to stand a much drier and hotter climate. It may reasonably be supposed that were *Dysdercus* able to go into a true resting stage, in which metabolism slowed down to an extent sufficient to enable the bug to do without food of any sort, and which would render it considerably less susceptible to climatic conditions, that its northward range would be greatly extended. *Agonoscelis* itself is limited by the degree of humidity present in its resting quarters, but owing to this long resting period the humidity necessary is very much less than in the case of *Dysdercus*. The foregoing data refer to macroclimatic conditions; almost equally

important are the conditions of microclimate. *D. fasciatus* is the only species which has been studied in this respect.

It has been described how the longer and severer dry season in the Nuba Mountains is an inhibiting factor both as regards distribution and reproduction; it may well be asked why in particularly dry years the bugs are not entirely exterminated. The answer lies in the favourable conditions of microclimate in the resting places selected by the bugs. Reference to the diagram of *D. fasciatus* (fig. 2) will show that all stages are common from the middle of August until between the end of December and the end of January; from the end of September until the middle of January the adults from flourishing colonies are fighting about from tree to tree, and frequently settling down in adjacent cotton cultivation. During this time colonies of bugs are prominent upon the trunks of the tebeldis, and in large numbers upon the ground feeding upon the fallen seeds; towards the beginning of February, however, these colonies are gradually dwindling, and there is much less activity on the ground, the bugs tending to cluster during the day, coming down to feed in the evenings and early mornings. Meanwhile those in the cotton are beginning to feel the effects of the steadily lowering humidity, rising temperature and lack of plant moisture, and are beginning to leave the dry cotton and cast back to the tebeldis. Soon only those bugs in the most favourable situations are able to carry on very slowly; the remainder have perished. During this critical period, those that have managed to find the best situations are usually clustered deep down in some large crack or fold in the bark, or even on the inside of the hollow trunks, where the maximum of shade and humidity are available. They now come out to feed only in the cool of the evening and the early morning, when they may be seen clustering round the fallen seeds, their stylets thrust in through the micropyles. If there are any shrubs or bushes around which are just showing next year's green shoots, the bugs are usually to be found clustered round their bases, sucking the juices of the young shoots, and apparently obtaining some measure of relief from the presumably locally raised humidity around the green plant tissues.

It is such relief obtained from microclimatic conditions of the most favourable localities that enables a nucleus, however small, to carry on until the approaching rains.

The following factors therefore are important as constituting a favourable locality for the bugs:—(1) A large tebeldi affording plenty of shade and lurking places; (2) a fairly heavy soil with a relatively high soil moisture content (this is important from the point of view of egg-laying); (3) fairly luxuriant undergrowth around the tree; (4) plentiful supplies of fallen fruit round the trunk; (5) a sheltered situation out of the main winds.

Certain other factors play a part in the ecology of *D. fasciatus*, such as the general flora other than their food-plants, the sowing date of cotton, the length of the cotton season, and the distribution of the tebeldis.

Although only two host-plants are known the bugs are very fond of feeding upon the juices of various other plants, particularly a number of herbaceous Malvaceae, presumably in order to obtain sufficient moisture which occasionally neither the tebeldi nor the cotton seed can supply.

The sowing date of the cotton crop is important, as the earlier the bolls mature, the sooner will fighting bugs settle down in the cotton cultivations; and similarly the earlier the cotton is cut out, the sooner will the bugs return to the tebeldis for the dry season.

The distribution of the tebeldis is of obvious importance, as when the bugs begin to flight from their parent trees in search of fresh breeding-grounds, the success or otherwise of their quest must obviously depend upon the relative abundance of their food-plants. The more scattered the tebeldis, the less chance will the bugs have of eventually settling down again, unless they happen upon a cotton cultivation.

Natural Enemies.

There are no natural enemies of any importance : certain REDUVIIDAE (*Phonoc-tonus lutescens*, chiefly) attack the nymphs and adults ; a Tachinid parasite (*Bogosiella pomeroyi*, Villen.) attacks all three species in Mongalla Province ; but so far no egg-parasite has been obtained from any of the species.

Control Measures.

As has been mentioned, work was started simultaneously in the Fung and Nuba Mountains Provinces, but was subsequently centred in the latter district. It was originally thought best to concentrate upon the colonies on the tebeldis in an attempt to exterminate as large numbers of the bug as possible. This was first attempted by means of painters' blow-lamps, burning the insects as they clustered on the bark of the trees. A very small kill was obtained with this method, however, owing to the small area covered by the flame and the rapidity with which the bugs hid themselves ; moreover it was particularly impracticable in dealing with the bugs feeding among and hidden under the debris and brushwood under the trees, and after a short time solo sprayers using commercial paraffin were employed and found to be extremely effective. The original method was to spray all known infested trees periodically through the season, but as the bugs were fighting from tree to tree, and from area to area, many were missed, and new colonies were constantly being formed on trees that had only just been sprayed. Subsequent research upon the bionomics of the bug confirming the fact that only one wild host-plant was available, and that the colonies of bugs were greatly attenuated during the dry season, it was deemed better to concentrate upon the bugs clustered on the tebeldis during the period from the end of January until the end of March.

According to Sudan legislation, the cotton-stalks should be cut out and burnt by a certain date, which varies in the different cotton-growing districts. It was clear that once the cotton had been destroyed, such bugs as had been breeding upon it had no option but to return to the tebeldis, therefore the ideal time in which to spray the bugs on the tebeldis would be some ten days after the destruction of the last of the cotton-stalks. Careful spraying in this manner gave very satisfactory results, very few, if any, of the bugs remaining alive upon the sprayed trees. It was naturally not always possible to guarantee that all the bugs had been destroyed, and in the possible survival of even only two or three individuals a further danger remained, for these would soon be able to breed up on the seeds lying about under the trees, the early rains in April and May assisting them by bringing up all kinds of fresh green growth.

The fact that the fallen tebeldi seed is the only adequate food supply is in this respect favourable to the bug, as there is always a sufficient amount round the base of the big trees, moreover, if all the brushwood and debris round the trees were swept up and burnt, the bugs might still manage to carry on until some more fruit fell off the tree. A further source of reinfestation is the possible arrival during the rains of some fighting bugs from an untreated tebeldi many miles away.

It seemed fairly clear from the foregoing data that the control of the wild food-plant was as important as the destruction of the actual colonies of bugs, accordingly experiments were undertaken on the pollarding and cutting back of the tebeldis in an endeavour to stop the trees from fruiting for one or more years. It was found that only complete cutting back of the trees was of any value, but that if a tree were to be cut back so as almost to be truncated, fruiting ceased for two, if not more, years, and when fresh growth occurred it was in the nature of osier-like twigs easily removable from the trees.

Final Control Measures (fig. 3).

It would appear from the foregoing that the obvious control measure would be the complete destruction of the tebeldi tree, eventually eradicating it entirely from



Fig. 3.

The diagram is identical with Fig. 2 except that it illustrates the altered conditions when the correct control measures are brought into play.

The thick line between July and August indicates the end of one season and the beginning of another. As a hypothetical case, the bugs have managed to live through the dry weather of 1929 and all stages are beginning to become common under the influence of the early rains and plentiful food supplies. The normal life-history is followed until about the middle of March 1930, at this date, represented by a short thick line pointing inwards from the humidity circle, the cotton is cut out and burnt, and all shed seed and debris are collected and burnt. This drives all the surviving bugs back on to the tebedis. About 10 days later the infested tebedis are then pollarded and sprayed, and all the fruit and seeds lying on the ground are collected and burnt, this is represented by a large thick line joining the humidity circle with the calendar in centre. From this date onwards such few bugs as have survived the above control measures are finding existence increasingly difficult until by the beginning of June, represented by the largest and thickest line of all, all the bugs are dead. From this point it should be impossible for any bugs to exist in the particular locality referred to even though reinfestation occurs from outside, as there will be no further food-supplies. Although small colonies may form late in the season in the cotton cultivations, they will perish directly the plants are cut out, and will never have time to reach any appreciable size.

the cotton-growing districts. Unfortunately certain other aspects of the question render this difficult. Firstly, the bark is extensively used by the natives in the manufacture of a fibre, in fact in some districts it is the only means they have of rope-making; secondly, in times of famine, the fruits are used in the manufacture of flour; and thirdly, the trees themselves are sometimes considered to be of aesthetic value and therefore to be preserved. The last mentioned reason is of course of no weight where the question of crop protection arises, but the two former are factors that must be taken into consideration, and so, assuming that the authorities desired to preserve these trees, a series of experimental control areas were started in 1930, upon the results of which the following recommendations for the control of *Dysdercus* in the Nuba Mountains were put forward:—(1) The cotton stalks should be cut out and burnt as soon after the picking season as possible, at least by the end of March; (2) all infested tebeldis should be sprayed about ten days after the destruction of the cotton stalks; (3) all infested tebeldis should be cut right back, and all fruit both on the tree and on the ground should be collected and burnt; (4) all small shrubs and trees within a radius of 30 feet from the tree-trunk should be cut down, and all debris in this area should be swept up and burnt.

The carrying out of these measures would mean that a truncated tree would remain and around it for 30 feet a clean bare patch of ground with no seeds left for any stray bugs to feed on, and no possibility in that particular locality of any subsequent seeds being available for a year or so. Further the more areas so treated, the less chance will there be of reinfestation from other untreated areas.

In the actual spraying of the trees great care should be taken over certain important details. Firstly, all small shrubs and trees should be cut down and piled up round the tebeldi trunk; all the debris, taking great care to miss no seeds, should then be swept up into the pile; the tree itself should then be sprayed. Particular care should be taken to see that all crevices and folds in the bark, and the interior of the trunk, if the tree be hollow, should be reached with the spray. The bugs do not cluster much above ten feet from the ground, so that operations can usually be confined to the base of the trunk; when this has been thoroughly sprayed, and large numbers of the bugs killed, the heaped up material round the base should be sprinkled with paraffin and set alight. The resultant flames, being fed largely by paraffin-soaked material are intensely hot, and every portion of the adjacent ground and every hiding place in the tree will be effectively reached. The sprayers used were double-acting and covered an effective area of about one square yard. The writer feels confident that if the above control measures were to be carried out over a period of a year or two they would eventually, to all intents and purposes, exterminate the genus *Dysdercus* from the Nuba Mountains.

Conclusions.

1. The genus *Dysdercus* in the Sudan may be divided into two groups, both geographically and economically. *D. fasciatus* in the northern rain country and *D. superstitiosus*, *D. nigrofasciatus* and *D. cardinalis* in the south.

2. The study of ecology, particularly of the factors of climate (macro and micro) and the investigation of wild host-plants are the most important aspects of the study of these insects. Considerable data have been amassed which have not been incorporated in this paper, and it is the hope and intention of the author to continue researches on these lines upon the various *Dysdercus* found in the Sudan.

3. Owing to the greater importance of the Nuba Mountains as a cotton-growing area, *D. fasciatus* has been studied somewhat more than the other species. It is believed that a satisfactory control has been evolved for this species.

Acknowledgments.

The author wishes to acknowledge the information on the bionomics and ecology of *D. superstitiosus*, *D. nigrofasciatus*, and *D. cardinalis*, which has so kindly been placed at his disposal by Mr. W. Ruttledge who has made some observations on these species in Mongalla Province.

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TRAPS FOR TSETSE-FLIES OF THE "CRINOLINE" AND "VENTILATOR" FORMS.

By C. W. CHORLEY,
Sleeping Sickness Inspector, Uganda.

With a Prefatory Note by C. F. M. SWYNNERTON,
Director of Tsetse Research, Tanganyika Territory.

(PLATE XI.)

Prefatory Note.

Having had the privilege of seeing something of Mr. Chorley's very fine work against *Glossina palpalis*, and having had four of his traps (of the types shown in Pl. xi, figs. 1, 2, 5) in experimental use myself, I would like to state that he has, in my opinion, done particularly excellent service in evolving several good types of trap for this tsetse-fly. They have not been properly tested yet against other species of tsetse. The choice of exactly suitable sites for the traps, as with all tsetse-traps, is a matter of considerable difficulty and demands expert knowledge, but if skilfully sited, the traps catch well. They represent the acme of cheapness. The mere tacking of a skirt on a Conical Hoop Trap (1912), a Hughen's trap (1919) or a Barrel Trap (Burnett 1918) makes a "Chorley" Trap for tsetse-fly. A mere sack or trouser-leg kept open by a hoop and with a non-return cage on the top suffices; and the trap collapses, like a lady's dress, into no space at all. It is simply, in some of its forms (as in Pl. xi, figs. 1, 2, 5), a very slight adaptation to tsetse of Richmond's Crinoline Trap for mosquitos, published in 1927 in the Government of India's Health Bulletin, No. 11; in its "ventilator" forms (e.g., fig. 3), it is an adaptation of the Wahl & du Plessis trap for blow-flies, published in 1923 in the Journal of the Department of Agriculture of South Africa—though even here the form most used has been cylindrical. There is also no reason why the entrance should not be yet higher up, under the overhanging eave of a platform lid, exactly as in Hodge's Garbage-can Trap of 1910 (see text-figure and Pl. xi, fig. 4).

Mr. Chorley, who is a keen naturalist and has spent some years in cruising about the islands of Lake Victoria in close contact with Lake conditions and *G. palpalis*, has shown great ingenuity and enthusiasm in the matter of his traps, not all of which are described here. Had his work allowed him to spend more time on them than it has, he would certainly have advanced even further, as (for instance) in the experimental study of scents attractive to *G. palpalis*. His very interesting general observations and a more complete account of his traps and their performance are to be published later.

A. Description of the Traps.

All the traps referred to in this paper consist firstly of a catching-cage with at least a top of wire-gauze. This cage may be box-like in form (Pl. xi, figs. 2, 5) with converging wire-gauze strips entering it to form a tectiform non-return passage; or square or spherical (figs. 3, 4), with a cone entrance as in the common "balloon" type of trap for *Musca domestica* (fig. 4); or a jar into which a removable cone is fastened for the retention and abstraction of the flies (fig. 1). From this cage—which may be a tin (fig. 3)—there depends a skirt or cylinder of doubled hessian, khaki cloth or other material, round or rectangular, which may vary from, say, eighteen inches

to three feet in length and the bottom of which, when the trap is suspended in position, may be from four to twelve inches off the ground. This "cylinder," kept open by hoops of withy, bamboo, thick wire or other material, or being of wood or tin (fig. 3), may be lined inside with dark cloth or have dark cloth guides running up inside it to or towards the catching cage, and its lower rim may be of dark cloth (figs. 1, 2) or may be painted outside and in. In the patterns now most used dark pieces of cloth project below the rim also for short distances as an extra advertisement and dark discarded puttees are used as the guides. Of the main traps invented :—

(1) *The Crinoline Sight Trap* is simply the above in cylindrical form, suspended by a swivel or a bicycle hub from a wire, a branch, or a stick laid across the top of two upright forked sticks (as in Pl. xi, fig. 2) and having attached to the catching-cage top (fig. 2), bottom or sides as may be convenient—or lower down (fig. 1)—four projecting arms below the ends of which are nailed petrol or other large tins bisected diagonally

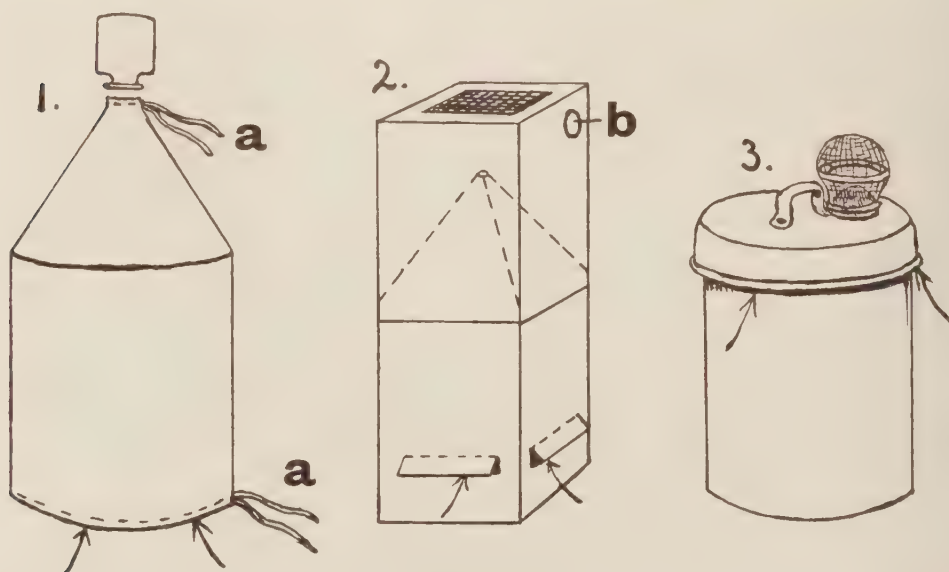


Fig. 1. 1. Richmond's Crinoline Trap for mosquitos, 1927: *a*, purse strings. 2. Wahl & du Plessis' Trap for blowflies, 1923: *b*, opening (papered over) for removal of flies. 3. Hodge's Garbage Can Trap for house-flies, 1910. The arrows indicate the route by which the flies enter the traps.

and forming wind-scoops. These in effect represent the cups of an anemometer, and by means of the wind keep the trap revolving. This, by drawing the attention of the flies, is believed to render the trap more attractive. The outside of the cylinder may have stripes (fig. 1) to add to the impression of progressive movement that the circling "scoops" give in any case. There are two forms of the Crinoline Sight Trap—wide, and narrow. In the former (figs. 1, 5) the catching cage being small in relation to the diameter of the crinoline, the latter comes off from it in the form of a "shoulder" and the whole is *exactly* of the shape and appearance of Richmond's Mosquito Crinoline Trap of 1927 (text-fig.). In the narrow form (fig. 2) the skirt hangs straight down from the catching cage and, with the hoop at its bottom, is only of the diameter of the latter. Intermediate forms may be used also. A trap with a jar has been illustrated in fig. 1, but the catching cage in fig. 2 has hitherto been most used in all forms.

(2) *The Crinoline Scent Trap* is the same trap with a scent attractive to the flies inserted therein or sprayed or smeared on some portion of it. The fat of cormorants and crocodiles has been found distinctly attractive; and extracts of animal glands, sebaceous and other, made by the Medical Entomologist, Kenya, in a preliminary experiment which the writer witnessed, appeared very attractive. Further experimentation is taking place in the direction of finding the most suitable scents.

(3) In the *Ventilator* or *Wahl & du Plessis* models of this tsetse-trap (Pl. xi, fig. 3), the upper part of the trap may be a petrol tin, or its equivalent, in this or other material. It may be painted, say grey or khaki, as in the figure, or be covered with or replaced by hessian or cloth. The lower part of the trap is of hessian or cloth depending from the tin, or may be tin also, covered, as in the figure, or painted, as in the original Wahl & du Plessis trap. Whether of tin, wood, or fabric, it may be entered from the sides, through ventilator-like openings instead of or in addition to the opening in the bottom, or it may have an opening round the rim of the bottom only, the rest of the bottom being closed. Both these forms have caught quite well.

The trap may be varied. It may be, and usually has been, cylindrical. A catching cage of another form may replace or rest on the top of the upper tin. When the uppermost tin is itself used as the catching cage, as in figure 3, it is best provided with a lid (as shown) instead of the papered opening of the original Wahl & du Plessis Trap. The openings are lined with dark cloth (which is best) or dark paint.

This trap (which revolves also and may in addition be striped as in fig. 1) may be used either as a sight trap, or, like the original Wahl & du Plessis Trap for blowflies (1923) or the Garbage Can Trap, with a scent bait. With the successful conclusion of the present promising experiments in scents it is probable that all the traps described in this paper will be used mostly as scent traps.

(4) *The Crinoline Cavern Trap* (Pl. xi, fig. 5). This was tried, found successful and suggested to the writer as a variant of his trap by the Director of Tsetse Research, Tanganyika. This trap, usable with or without scent, is a Crinoline Trap lined inside with dark cloth, preferably black, and is laid on its side on the ground, or, for the avoidance of ants, is suspended in that position a short distance above it.

In a successful form of this trap since evolved by the writer the attractive dark opening, a huge one, is in the side and the trap hangs or stands normally, vertically.

B. The Traps compared with some early Traps.

Actually, the Crinoline Trap (Pl. xi, figs. 1, 2) used without scent is simply a slight modification of the Crinoline Trap for mosquitos, used by Richmond & Mendis in the Punjab and published first by Covell in 1927 (text-fig). The main difference is that in the mosquito trap the catching cage consists of a plain inverted glass jar, daily inserted in the top of the crinoline for the removal of the mosquitos, which, when the crinoline is disturbed, fly up into it; whereas in the Crinoline trap for tsetse the glass jar has a removable entrance cone of wire (fig. 1) and remains permanently in the top of the crinoline, or may be replaced by a non-return cage of wood and gauze (figs. 2, 5), or gauze and tin (fig. 3). The present Crinoline trap differs also from the old Crinoline in the rotary apparatus described (fig. 2) Shircore⁷ first suggested movement in general and rotation in particular for tsetse traps in 1916, and Swynnerton⁸ used a rotating trap in 1922. In the Cavern trap (fig. 5) the distant attraction consists in the conspicuous cavernous black mouth of the trap, probably suggesting a breeding or hiding place; and all the traps (the Ventilator model in particular in virtue of its form), attracting as they do by scent as well as by sight, come into the closest of relations with some of the old blowfly traps.

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EXPLANATION OF PLATE XI.

- Fig. 1. The Crinoline Trap as adapted to tsetse-flies. The jar, if used, should be fitted with a removable non-return cone. A rotary apparatus, indicated here by the wooden rod, is added. Vertical or diagonal markings of white or other colours are painted on the outside of the crinoline to give the impression of progressive movement as the whole trap revolves. The dark, swollen rim below is an attraction to the mouth of the trap.
- Fig. 2. The narrow Crinoline Trap for tsetse-flies. The "skirt" hangs straight down like a trouser-leg; the most usual form of catching cage is shown, as is the rotary apparatus of four diagonally-bisected petrol tins dependent from two horizontal rods in the form of a cross. The trap is shown set in a good position: the fly movements are along the border of this barrier of dense bush.
- Fig. 3. The Ventilator Trap—*i.e.* the Wahl & du Plessis Trap in a form adapted to catch tsetse-flies. The lower part of the trap is here covered with hessian; the ventilator-like openings are enlarged; dark cloth (in this instance) guides into each from below; a lid is provided for the catching cage instead of the papered-over hole of the "Wahl & du Plessis." The rotary apparatus, not shown, would be on the top as in Fig. 2.
- Fig. 4. Suggested adaptation of the Garbage-can Trap, illustrated very roughly here by means of some sacking and a bin. The lid would best be of tin or of wood with merely a dependent fringe. The body would best be composed of, or covered with, fabric, and it would be suspended and revolve like the others. Any kind of catching cage might be placed over the opening.—*Cf.* Swynnerton: Cylindrical Screen Trap, SCii, Bull. Ent. Res., xxiv, p. 83.
- Fig. 5. The Cavern Trap. A crinoline trap laid or suspended on its side, as shown here, or a crinoline or Wahl & du Plessis form with a cavernous opening in its side. Note the black inside lining.



Fig. 1.



Fig. 2



Fig. 3

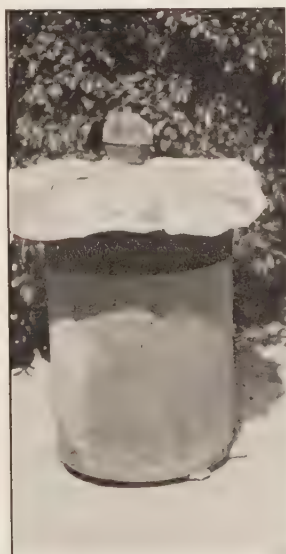


Fig. 4.



Fig 5

Examples of Traps for Tsetse Flies.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st January and 31st March, 1933, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance :—

Mr. A. M. ALTSON :—5 Diptera ; from Northern Rhodesia.

Major R. A. BAGNOLD :—7 Diptera, 17 Coleoptera, 5 Hymenoptera, 6 Lepidoptera, 3 Rhynchota, 22 Orthoptera, 4 Planipennia, and 3 Scorpions ; from the Libyan Desert, Egypt.

Dr. J. G. BETREM :—300 Parasitic Hymenoptera and 60 cocoons ; from Java.

CHIEF ENTOMOLOGIST, PRETORIA :—12 Diptera, 82 Coleoptera, 217 Parasitic Hymenoptera, and 14 Rhynchota ; from South Africa.

CHIEF VETERINARY OFFICER, BURAO :—7 Orthoptera ; from British Somaliland.

Mr. A. F. CLARK, Forest Entomologist :—1 species of Aphidae ; from New Zealand.

Mr. G. H. CORBETT, Government Entomologist :—17 Diptera, 86 Coleoptera, 77 Parasitic Hymenoptera, 37 other Hymenoptera, 207 Lepidoptera, 18 Rhynchota, and 4 Psocidae ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—567 Coleoptera ; from Kenya Colony.

Dr. N. CUSCIANNA :—35 Orthoptera ; from Italy.

Mr. A. CUTHBERTSON, Assistant Entomologist :—2 Asilidae and prey, 24 other Diptera, and 3 Rhynchota ; from Southern Rhodesia.

Dr. J. DAVIDSON, Waite Agricultural Research Institute :—40 Thysanoptera and 1 species of Coccidae ; from South Australia.

Mrs. V. DICKSON :—13 Coleoptera ; from Arabia.

DIRECTOR OF AGRICULTURE, IBADAN :—8 Coleoptera ; from Nigeria.

DIRECTOR OF PUBLIC WORKS, LAGOS :—9 Coleoptera and 30 early stages, 26 Formicidae, and 180 Isoptera ; from Nigeria.

Mr. J. L. FROGGATT :—2 Tabanidae, 59 other Diptera, 174 Coleoptera, 15 Parasitic Hymenoptera, 52 other Hymenoptera, 69 Rhynchota, and 39 Orthoptera ; from New Guinea.

Mr. J. C. M. GARDNER, Systematic Entomologist :—24 Coleoptera, 106 Parasitic Hymenoptera, and 37 Lepidoptera ; from the United Provinces, India.

Mr. F. D. GOLDING, Senior Entomologist :—60 Orthoptera ; from Nigeria.

Mr. P. v. d. GOOT :—39 Coleoptera and 13 Lepidoptera ; from the Dutch East Indies.

Mr. F. P. GOSECO :—27 Orthoptera ; from the Philippine Islands.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—3 Curculionidae ; from South India.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—20 Chironomidae, 27 Coleoptera, 80 Parasitic Hymenoptera, and 6 Rhynchota ; from the Punjab, India.

Mr. W. GREENWOOD :—4 Diptera, 14 Coleoptera, 150 Lepidoptera, and 12 Rhynchota ; from the Fiji Islands.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—2 Parasitic Hymenoptera ; from Uganda.

Mr. E. HARGREAVES, Government Entomologist :—10 Culicidae, 3 Tabanidae, 198 other Diptera and 24 puparia, 552 Coleoptera, 230 Parasitic Hymenoptera and 2 cocoons, 151 other Hymenoptera, 565 Lepidoptera, 20 Thysanoptera, 8 species of Coccidae, 2 species of Aphidae, 3 species of Aleurodidae, 341 other Rhynchota, 2 Psocidae, 135 Orthoptera and 20 exuviae, 44 Dermaptera, 6 Planipennia, 3 Ephemeridae, 29 Trichoptera, and 2 Ticks ; from Sierra Leone.

Mr. G. F. HILL, Senior Entomologist, Canberra :—4 Isoptera attacked by fungus ; from Australia.

Mr. W. D. HINCKS :—38 Coleoptera ; from various localities.

Mr. G. H. E. HOPKINS, Medical Entomologist :—5 Lepidoptera and 394 Mallophaga ; from Uganda.

Dr. J. C. HUTSON, Government Entomologist :—340 Parasitic Hymenoptera and 100 cocoons, and 23 Lepidoptera ; from Ceylon.

IMPERIAL ENTOMOLOGIST, PUSA :—44 Isoptera ; from India.

INDEPENDENT BIOLOGICAL LABORATORIES, TEL-AVIV :—2 Formicidae, 3 Collem-bola, and 46 Spiders ; from Palestine.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—43 Rhynchota ; from Java.

Mr. G. P. JUNG :—26 Parasitic Hymenoptera ; from China.

Mr. K. H. L. KEY :—1 Ichneumonid ; from South Africa.

Mr. T. W. KIRKPATRICK, Entomologist, Amani :—2 Coleoptera, 2 Chalcididae, and 28 Rhynchota ; from Kenya Colony.

Dr. W. A. LAMBORN, Medical Entomologist :—2 Siphonaptera, 8 Tabanidae and 4 early stages, 38 other Diptera, and 30 early stages, 3 Coleoptera, 11 Parasitic Hymenoptera, 6 other Hymenoptera, 13 Lepidoptera and 8 early stages, 5 Rhynchota, 2 Planipennia, 7 Hemimeridae, and 9 Mites ; from Nyasaland.

Mr. R. A. LEVER, Government Entomologist :—80 *Lyperosia*, 232 other Diptera, 308 Coleoptera, 17 Parasitic Hymenoptera, 38 other Hymenoptera, 18 Lepidoptera, 100 Isoptera, 72 Rhynchota, 14 Orthoptera, 10 Mallophaga, 22 Spiders, 6 Scorpions, 10 Parasitic Worms, 2 Shells, 9 Birds, 2 Bats, and 2 Mammal skulls ; from the Solomon Islands.

Dr. LL. LLOYD :—45 Diptera ; from England.

Mr. J. B. LOUGHNANE :—11 species of Aphidae ; from the Irish Free State.

Mr. H. MANEVAL :—97 Parasitic Hymenoptera and 10 cocoons ; from France.

Prof. F. J. MEGGITT :—26 Diptera, 21 Coleoptera, 7 Hymenoptera, 2 Lepidoptera, 1 species of Coccidae, 1 species of Aphidae, 11 other Rhynchota, 26 Orthoptera, and 3 Spiders ; from Burma.

Mr. H. M. MORRIS, Government Entomologist :—3 Culicidae, 6 Nycteribiidae, 206 other Diptera, 9 Coleoptera, 45 Lepidoptera, 159 Rhynchota, 21 Orthoptera and 9 Dermaptera ; from Cyprus.

Mr. J. MUGGERIDGE, Government Entomologist :—37 Thysanoptera ; from New Zealand.

Mr. H. K. MUNRO :—30 Trypetidae ; from South Africa.

MUSÉE DU CONGO BELGE, Tervueren :—1,496 Coleoptera ; from the Belgian Congo.

Mr. F. B. NOTLEY, Assistant Entomologist :—16 Diptera, 58 Parasitic Hymenoptera, and 2 Rhynchota ; from Kenya Colony.

Mr. & Mrs. J. OGILVIE and Miss A. MACKIE :—1,821 Diptera, 999 Coleoptera, 112 Parasitic Hymenoptera, 2,290 other Hymenoptera, 808 Lepidoptera, 29 Isoptera, 804 Rhynchota, 829 Orthoptera, 40 Planipennia, 125 Odonata, 2 Ephemeridae, 7 Trichoptera, 5 Plecoptera, 20 Ticks, and 5 Spiders ; from various African localities.

Mr. J. OGILVIE :—24 Diptera, 4 Coleoptera, 2 Parasitic Hymenoptera, 22 other Hymenoptera, 30 Lepidoptera, 8 Rhynchota, 2 Orthoptera, 3 Chrysopidae, and 6 Odonata ; from Bermuda.

Mr. R. W. PAINE :—8 Diptera ; from Java.

Mr. H. M. PENDLEBURY, F.M.S. Museum :—264 Coleoptera and 22 Chrysidae ; from Malaya.

Rev. O. PIEL, S.J. :—4 Parasitic Hymenoptera, and 121 Orthoptera ; from China.

Mr. H. A. PORTER :—17 Isoptera, a Queen's cell, and sample of wood attacked ; from Nigeria.

Mr. J. W. S. PRINGLE :—11 Parasitic Hymenoptera ; from England.

Mrs. M. C. RANT :—106 Lepidoptera, 134 Orthoptera, and 3 Planipennia ; from Arabia.

Mr. P. REGNIER :—180 Parasitic Hymenoptera and 23 cocoons, and 58 Orthoptera ; from Morocco.

Dr. A. REYNE :—22 Coleoptera and 6 early stages, and 50 Hymenoptera ; from the Dutch East Indies.

Mr. A. H. RITCHIE, Government Entomologist :—2 Coleoptera, 2 Psocidae, 1 species of Coccidae, and 180 Collembola ; from Tanganyika Territory.

Mr. T. W. RUSSELL, Plant Pathologist :—50 Parasitic Hymenoptera, and 150 Thysanoptera ; from Bermuda.

Dr. G. RUSSO :—6 Coleoptera, 16 Parasitic Hymenoptera, and 13 Rhynchota ; from the Italian Somaliland.

Mr. NIHAT SCHEWKET BEY :—1 species of Coccidae ; from Turkey-in-Asia.

Mr. H. W. SIMMONDS, Government Entomologist :—1 Moth and 1 species of Coccidae ; from the Fiji Islands.

Mr. H. D. SMITH :—2 Parasitic Hymenoptera ; from France.

Mr. O. H. SWEZEY :—31 Coleoptera and 18 genital preparations ; from various localities.

TEA SCIENTIFIC OFFICER, NILGIRIS :—6 Diptera, 23 Coleoptera, 4 Parasitic Hymenoptera, 16 Lepidoptera, 12 Thysanoptera, 1 species of Aphidae, 19 other Rhynchota, and 2 Orthoptera ; from South India.

Mr. T. L. TSOU :—40 Orthoptera ; from China.

UNITED STATES PROTECTION & INDEMNITY AGENCY, LONDON :—7 Coleoptera ; from the U. S. America.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—35 Culicidae, 60 *Phlebotomus*, 102 other Diptera, 500 Coleoptera, 34 Lepidoptera, 160 Rhynchota, and 126 Orthoptera ; from the Sudan.

Mr. W. E. WHITEHEAD :—9 Mallophaga and 4 Anoplura ; from Canada.

Dr. F. ZACHER :—86 Parasitic Hymenoptera ; from Germany.

THE FOOD OF THE RED-BILLED OXPECKER, *BUPHAGUS*
ERYTHORHYNCHUS (STANLEY). W

By R. E. MOREAU,

East African Agricultural Research Station, Amani.

The Red-billed Oxpecker, or Tick-bird, is the East African representative of a genus that has always excited interest by reason of the peculiar feeding habits of its members. They obtain the whole of their food on the bodies of the larger Herbivora, and their abnormally sharp claws permit them to travel in any direction and to visit every spot on the bodies of their hosts. It is obvious that to stock-owners birds of these habits must be of economic importance, but veterinary, ornithological and entomological literature alike have failed to provide any record of an investigation of their food.*

In the absence of published data application was made to various authorities for their opinions and for any detailed information they might have. Astonishingly diverse replies were given. The head of a veterinary laboratory in one of the East African dependencies wrote as follows: "I believe they do pick off ticks, although I doubt if they eat these; their object being to find a wound. When they have succeeded they feed on the exposed raw tissue." Another local veterinary authority remarked: "They cause a great deal of damage through the sores they produce in stock." A gamewarden said: "I always regarded the oxpecker as an unmitigated nuisance and pest. The prevalent idea that this bird frees domestic stock of ticks appears to be entirely erroneous. . . . These birds feed mainly on the raw tissue of open wounds and it is by their action that the open wounds usually occur." Other observers of wide experience are less downright. Thus A. Blayney Percival ("*A Game-Ranger on Safari*," pp. 344-345): "Its food consists entirely of the parasitic insects found among the hair, and the nest is built of the hair collected from the hosts . . . Provided that the beast has no abrasion on the skin those attentions are only beneficial, but if there be a scratch or open wound, however trifling, that becomes the centre of attraction, and the busy beaks quickly enlarge it into a serious sore." †

Emphasis had been frequently laid on the oxpecker's potentialities as a carrier of various diseases, especially rinderpest, anthrax and nagana. Regarding this last, the Director of Veterinary Services, Pretoria, has kindly drawn attention to a reference by Dr. H. H. Curson to the oxpecker's possible agency (S. Afr. J. Nat. Hist., vi, 1928, p. 181) and obtained the following supplementary notes from the author: "*Buphaga* is undoubtedly a factor in the mechanical transmission of nagana. Although not proved experimentally, there is abundant field evidence to justify this conclusion. It must be remembered that not only do the birds eat ticks, but they also drink blood from the sites where the ticks have been attached. . . . With blood-soiled beaks they fly to neighbouring cattle and cause similar damage. In this way artificial mechanical transmission of nagana may be brought about."

In other words the preponderance of experienced and authoritative opinion condemns the birds. Some observers are not prepared to admit that they eat ticks

* Thanks are due to the Director of the Imperial Institute of Entomology for interesting himself in the search for published data.

† It will be noted that by implication the last part of this extract contradicts the statement in the first sentence that the oxpecker's food consists "entirely" of "insects" (read as including ticks).

at all ; others attach but little importance to any good that may be done in that way and concentrate attention on the birds' powers for harm. In general I have found by casual enquiries, whenever opportunity offered, that Europeans are inclined to condemn the birds and Africans to commend them. One need not presume to oppose the *obiter dicta* of a Masai herdsman to the pronouncements of a Veterinary Director, but it is clear that there is room for an impartial investigation of the oxpecker's economic status.

As an ornithologist with very limited time at my disposal, I cannot hope to deal comprehensively with this complex question. It is obvious that a period of full-time work in the field and specialist knowledge on several lines would be necessary to produce authoritative conclusions. In particular, the investigator should know something of the biology of the various cattle-parasites eaten by the birds ; of their potentialities as vectors of disease ; of the digestive processes of the birds ; and of the appearance of blood and scab-material at all recognisable stages after ingestion by both birds and parasites. Such specialist knowledge has not been at my disposal, and moreover my routine duties at the Research Station fill official hours. In the circumstances all that is claimed for the investigation recorded in this note is that it provides *prima facie* evidence that the potential value of the red-billed oxpecker as a destroyer of parasites of all kinds has been underestimated.

Details will be given of the stomach contents of 58 birds. It was hoped to be able to examine a larger number from widely separated localities, but much practical difficulty has been met with in getting material. I have to express my obligations to a number of correspondents, of whom Mr. J. T. Purvis, of the Tanganyika Veterinary Department, must be mentioned as having provided enthusiastic assistance in both making observations and procuring specimens. Grateful thanks are due to Dr. E. A. Lewis, of the Kenya Veterinary Department, for undertaking the identification of the ticks found in the stomachs. Without his help this note would have been much more incomplete than it is. Acknowledgment must also be made to the Chief Veterinary Research Officer at Kabete for allowing him to undertake the work, and to my own Director for his personal interest and for technical assistance in the stomach examinations.

Field Observations.

Oxpeckers attend all the larger Herbivora, except the hippopotamus and the elephant—which has a notoriously tender skin and a long trunk to protect it. With the rhinoceros its association is particularly close. Experienced observers assert that the bird acts as sentinel for the rhino to a far greater extent than for other hosts. In fact, the relationship in that particular case may almost be called symbiosis. The oxpecker will stick remarkably closely to its host ; I have seen them clinging to the flanks of a greater kudu (*Strepsiceros kudu*) going at full speed.

All kinds of domestic stock receive the oxpecker's attention. I have seen them on horses, mules, donkeys, cattle, sheep, goats and pigs. They are stated to frequent camels also. They pitch indiscriminately on any part of a beast and work it all over with rapid jerky movements. Their preternaturally sharp claws enable them to move up and down vertical surfaces as easily as a woodpecker on a tree-trunk. Some of my correspondents suggest that the oxpeckers show a preference for different parts of the animals' bodies, but this I am unable to confirm. As a rule, the birds' attentions do not seem to be unwelcome. The beasts are surprisingly tolerant of the birds even when they are on their faces. Occasionally a bull may be seen to try and shake them off his head or a donkey to resent their presence anywhere on his hide. But they are very difficult to get rid of, and if forced to leave a beast, they immediately settle on another. In fact their movements resemble those of blow-flies on meat in their pertinacity and appearance of brainless tropism, so that personally I find them somewhat unpleasant to watch. They are not easy to observe

minutely. They do not often permit a European to approach very close, and nearly always they put, and keep, between themselves and an observer, as much as possible of the beast they are working over.

Where cattle are kraaled at night, I have seen the oxpeckers come and sit hungrily on the roof in the early morning, waiting for their hosts to emerge. There is no evidence of definite feeding-times, though, locally, where food is very abundant the birds might be expected to fill themselves early in the morning and depart until they felt the need of another meal. It is not uncommon for a party of oxpeckers to rise off a herd and fly off out of sight as if they had made up their minds either to rest or to seek a more profitable pasture. But they do also take their ease on their hosts. Oxpeckers often sit flat, as if brooding, on a cow's back, or even lying on one side with wing extended as if to bring the maximum possible area of their bodies in contact with the hide.

In my experience the bird does not as a rule use its powerful bill like a pickaxe, as, for example, crows and ravens do. The usual motion seems to be a rapid "scissoring," which may be carried out at all angles from the vertical to flat on the host's hide. It is obvious that in the latter position such a mode of operation must be most effective for locating parasites fast on the skin. I have not been able to satisfy myself whether in this exploratory "scissoring" the mandibles actually meet or not. I doubt whether they do, and certainly no click is audible when they approach each other. Given feeding habits of this nature it is not surprising that oxpeckers should disappear in districts where dipping is extensively practised. Whether they actually peck the hide or not, they would get quite enough arsenic to poison themselves from the hair they are continually working through.

There is plenty of field-evidence for the consumption of blood-tissue from the host. Though some of it is uncritical, the greater part cannot be doubted. For example, Mr. F. J. Hood, Veterinary Officer at Dodoma, writes: "I personally have observed these birds picking at wounds, particularly in the heels of cattle, in fact the grade bull returns almost every day with all four heels bleeding as a result of the activities of these birds." And Mr. J. T. Purvis after a good deal of critical observation concludes: "I am now convinced that oxpeckers will feed from open sores or wounds when they find them, but I am not prepared to say that they cause such wounds." He goes on to mention the case of an ox with a number of wounds. "All which could be bandaged healed rapidly, but those which it was impossible to bandage owing to situation were kept open and raw by tick birds."

In this connection it is also interesting to note that he found four oxpeckers battenning on impala meat hung out to dry. This is the one observation I have been able to collect, from any source, of an oxpecker obtaining food in any other way than from the body of a living animal. Therefore the evidence is good that anything found in the stomachs has been collected in the latter situation. Personally, I have been astonished at the small amount of obvious damage caused by these birds. An isolated herd of 29 native cattle, which were found on every visit of inspection to be attended by a party of oxpeckers, were examined carefully for wounds, but not a single one was discovered. At Kongei, in the West Usambaras, about 100 head of mixed stock showed no obvious wounds, and none could be pointed out to me by their owner (an opponent of oxpeckers) except on one pig. This creature had the basal half of both ears raw. I kept a close watch on it for some hours. Oxpeckers visited it, snapped at flies approaching the wounds, and I am practically certain that they nibbled at the raw surfaces. The astonishing thing is that the pig showed not the slightest resentment at this operation, which ought to have been exquisitely painful. It did not even shake its ears.

This is the only occasion in which oxpeckers have been observed to take flies, but as will be evident from the stomach contents recorded later, biting flies form an important element of the total food.

The birds are often locally, and apparently capriciously, distributed. For instance, on a journey through the West Usambaras I found them common on European stock at Kongei and Magamba, few in number at Kwai, rare on the native cattle at Mlalo, and entirely absent from the numerous herds belonging to the Wambugu. One factor is the prevalence or history of dipping in each locality. Mr. Purvis has come to the conclusion that another is the prevalence of ticks. From the point of view of those who doubt whether ticks are an important element in the birds' diet this is, of course, begging the question. But the stomach analyses support the credibility of Mr. Purvis's hypothesis. Certainly there is a good deal of local movement. There are, however, narrow limits to their enterprise in seeking new pastures. Oxpeckers are unknown at Amani, although cattle have been kept here for over 20 years, and although a native herd in another clearing about 9 miles to the north always has some of these birds in attendance.

I have been astonished by the large number of oxpeckers that find sustenance on any particular herd. I made a series of observations extending over a fortnight on about 50 head of cattle and 50 of smaller stock, noting the number of oxpeckers visible on them on every occasion when they were examined. The average, taken over all hours of the day, was 21. At times the birds settle densely on individual beasts. I have seen 5 on one sheep; Mr. Purvis records 17 on a single donkey. On an isolated native herd at Kwamkashi in the East Usambaras, averaging about 30 beasts, I have seen as many as 11 birds and usually at least 7. Mr. Purvis at my request kindly made daily observations on a small herd at Arusha on similar lines to my own. On 13 head of stock the average total number of oxpeckers was astonishingly high, over 5. Taken in conjunction with the figures given above these seem to show that an oxpecker can find continuous sustenance on 3 head of cattle, that is to say, on something like 150 square feet of hide. This is a surprising result, and the more so when we consider that the oxpecker is not a small bird. A further reference will be made to this point later, when the stomach contents are discussed.

Examination of Stomach-contents.

Experience has led me to think that purely macroscopic examination of stomach-contents untreated in any way may give erroneous impressions. It appears, in fact, that rough and ready examination in the field may be of doubtful value. Many stomachs on being opened disclose what is practically a bolus of hair. Even after teasing out in water the result is often a murky agglomeration of hair and finely comminuted material in which it is difficult to distinguish anything more complete that may be present. Usually the material has had to be boiled for a few minutes with caustic potash before it could be sorted.

The state of the blood found in the stomachs and the conclusions to be drawn therefrom are obviously of great importance in attempting to assess the economic status of the birds. I cannot pretend to deal satisfactorily with this difficult point. It would probably have to be investigated from the beginning by a competent biochemist. One or two relevant facts have however emerged. In the first place, a large proportion of all the ticks swallowed are unbroken. It follows that their contents do not become available to the oxpecker until the somewhat resistant envelope formed by the tick's cuticle has been broken down by the digestive juices. (The oxpecker's digestion is not aided by grit.) Nor is the appearance of the blood contained in the tick necessarily changed until quite late in the process of digestion by the bird. I have had stomach material in alcohol for weeks, and when the ticks included in it have been punctured with a dissecting needle, what looked like fresh blood has oozed out. I have even known the same thing to happen after a brief "cleaning up" of the material with potash. Again, in several stomachs clots have been noted which would readily be put down as derived from scabs. Treatment

of the material with potash converted these clots into lumps of tenacious jelly. I examined several of these under the dissecting microscope for signs of structure and found some of them to be intimately associated with the remains of ticks far gone in the process of digestion. These were practically transparent and would escape any other than careful examination. Apparently, then, the blood contained in a tick may retain its identity and a certain cohesion when the enveloping sac has been practically digested away. This may depend on the stage reached by the digestive processes of the tick at the time it was swallowed by the oxpecker. In any case there are grounds for suspecting that what appear at first sight to be scabs are in some cases really derived from ticks.

Contents of Individual Stomachs.

In Table I the number given in each case is the minimum compatible with the remains actually seen. Thus 51 Dipterous wings are given as 26 insects although the number represented is almost certainly higher. Where the material is very much digested or fragmentary, it is often impossible to make a complete count without an inordinate expenditure of time. The number of individuals has in those cases been estimated to the nearest 10.

Note has been made of every occasion on which hair and any form of blood or tissue was discernible.

Tick material that was thought to be possibly identifiable by species was referred to Dr. Lewis. The results are given in Table II. The numbers include ticks at all stages of development.

I am indebted to several correspondents for particulars of stomachs examined by them. The details are reproduced below, with the caveat that in no case is it known how minutely the examination was carried out. As I have already stated, I have found that a rough and ready inspection may be quite misleading.

- (i) The late Mr. E. Montgomery, Veterinary Adviser to the Colonial Office, was good enough to give me particulars (from memory) of some notes he made at Nairobi in 1910. Ticks were plentiful, but when 27 birds were shot and their stomachs examined "in no instance was anything seen that could be deduced as a portion of a tick. Some hair, what appeared to be macerated scabs of skin origin, and a little grit, were noted."

(ii) Mr. J. T. Purvis :—

No. 1, Mondul, 9.v.31. "Large proportion ordinary flies, 7 ticks. . . . Several small beetles."

No. 2, Longido, 4.vii.31. "Large amount of congealed blood and small amount of what appeared to be epidermal tissue. No insect of any sort could be found."

No. 3, Engare Nanyuki, 15.ix.31. "56 ticks. . . . 1 piece of epidermal tissue."

No. 4, Engare Nanyuki, 15.ix.31. "4 ticks and large amount of hair."

No. 5, Engare Nanyuki, 5.x.31. "49 ticks. . . . and 4 pieces of epidermal tissue $\frac{1}{4} \times \frac{1}{4}$ cm. to $\frac{1}{2} \times 1$ cm."

No. 6, Engare Nanyuki, 12.x.31. "37 ticks, congealed blood (of partly digested ticks?), 2 small flies."

(iii) Mr. J. M. Clark, Bukoba :—

No. 1, "30 ticks of all sizes up to 8 mm.; small patch of skin with hair 4 mm. \times 8 mm.

No. 2, "12 ticks of all sizes up to 8 mm. Some free hairs."

No. 3, "21 ticks, all sizes up to 9 mm., a few free hairs."

All contained "free dark blood but no other foodstuffs so far as the naked eye could tell. . . ."

(iv) Mr. F. J. Hood, Dodoma :—

No. 1, "Blood, ticks and flies (*Musca* and *Stomoxys*)."

No. 2, "Blood, and a piece of blood-clot."

No. 3, "A few ticks and flies. . . . Stomach practically empty."

No. 4, "Blood, ticks, flies and a few pieces of grit the size of a pin-head."

It will be seen that Mr. Montgomery's experience is very different from my own and from that of the other observers. Both Mr. Clark and Mr. Hood refer to free blood as being present in 6 out of their 7 specimens. This again is in striking contrast to the details given by Mr. Purvis and in Table I.

TABLE I.

No.	Source	Ticks	Diptera	Other Organisms	Other matter
1	Maramba, East Usambaras. Shot off small native herd	53 and some eggs	4 Tabanid sp.	—	Much hair.
2	do. (10.iv.31)	17	At least 8	—	Much hair and one small amorphous mass (? scab).
3	do.	15	? <i>Stomoxys</i> sp.	1 louse	do.
4	Kwamsangudi, E. Usambara (native herd) 28.ii.31	33	9 <i>Calyptera</i> sp. Several do.	1 louse	—
5	do.	57	1 do. and 2 midge-like	1 Phasmid 1½ in. long	—
6	do.	68	4 <i>Calyptera</i> sp., 10 midge-like	—	—
7	do. x.31	11	—	—	1 small scab and 1 blood-clot; fragment of grass.
8	do.	159	—	—	Some hair and fragments of grass.
9	do.	15	—	—	Much hair and very finely divided matter (? remains of Diptera).
10	do.	6	—	—	do., also one very small blood-clot.
11	do.	13	3 small and 2 <i>Simulium</i> sp.	2 Phasmids, 2 in.—3 in. long	Very little hair; 1 fragment of skin 0.4 cm. ² and fragment of ? scar-tissue.
12	do.	4	2 ? <i>Stomoxys</i> sp.	—	Mass of hair and very finely divided matter.
13	do.	9 and much digested remains of many more	5 do. and many wings of <i>Simulium</i> sp.	—	do.
14	do.	60	10 <i>Simulium</i> sp.	2 small Orthoptera	do.
15	do.	6	1 do.	—	do. and 1 very small blood-clot.
16	Kongei, West Usambaras; shot off European stock (not hand-dressed), 1.viii.31	12	5 <i>Stomoxys</i> sp. 21 do.	—	—

TABLE I—continued.

No.	Source	Ticks	Diptera	Other Organisms	Other matter
17	Kongei, West Usambaras; shot off European stock (not hand-dressed), 1.viii.31	5	26 <i>Stomoxys</i> sp.	1 spider's egg-bag with newly emerged young	Much hair.
18	do.	8	50 do.	—	do.
19	do.	15	—	Elytra of a small beetle	—
20	do.	—	60 <i>Stomoxys</i> sp.	—	Very little hair.
21	do.	55	4 do.	—	—
22	do.	12	6 do.	—	1 massive blood-clot from which were dissected remnants of the skin of a very large tick; 2 egg-shaped blood-clots believed to have been derived from ticks.
23	do.	5	40 do.	—	—
24	do.	4	20 do.	1 louse	Much very fine hair.
25	do.	3	10 do.	—	Some hair; much very finely divided flocculent material in which no structure could be discerned; 1 scrap of (?) scar-tissue.
26	do.	11	25 do.	—	—
27	do.	4	16 ? sp.	—	1 blood-clot approx. $\frac{1}{2}$ cc.
28	do.	13	20 ? sp.	—	6 small blood-clots.
29	do.	28	1 Hippoboscid 2 <i>Stomoxys</i> sp. and much debris	—	Much short hair.
30	do.	12	3 do. do.	—	do.
31	do.	20	3 do. do.	—	After boiling with potash about a dozen small ovoid blood-clots became visible; microscopic examination showed scraps of almost completely digested and transparent integument hanging to them; in one case ticks' legs were identifiable.
32	do.	1	2 <i>Stomoxys</i> sp.	—	Much very finely divided material.
33	do.	21	8 do.	—	—
34	do.	12	Much debris	2 <i>Haematopinus</i>	Some fine hair.
35	do.	29	do.	—	Much hair.
36	do.	47	4 <i>Stomoxys</i> and much debris	—	do. and 1 minute spiny seed.
37	do.	7	Much debris	2 <i>Haematopinus</i>	do.
38	do.	118	—	—	do. N.B. Two "meals" represented: 40 of the ticks freshly swallowed, remainder much digested and colourless.
39	do.	2	2 <i>Stomoxys</i>	1 large piece of brown chitin	Much hair.
40	do.	15	1 do. 1 Hippoboscid	—	Some hair.
41	do.	23	Debris	—	A little hair.
42	do.	65	3 <i>Stomoxys</i> and debris	—	Some hair.
43	do.	50	13 do. and much debris	—	Much hair and 1 minute pebble.

TABLE I—continued.

No.	Source	Ticks	Diptera	Other Organisms	Other matter
44	Magamba, West Usambaras; on native cattle, 22.vii.31	9	—	—	Much hair and very finely divided matter; a scrap of indiarubber-like substance penetrated by short black hairs; ? a scab.
45	do.	9	—	—	Much hair and very finely divided matter; scrap of skin about 0.2 cm. ²
46	do.	44	1 (? sp.)	—	Little hair; very finely divided matter.
47	do.	39	—	—	Mass of hair.
48	do.	8	—	—	do.
49	Mlalo, West Usambaras; on native cattle, 28.vii.31	124	1 ? <i>Stomoxys</i>	—	Very little hair.
50	do.	94 and some debris	—	—	Scrap of tissue weighing 0.18 gm. air-dry.
51*	Mbulu, 3.viii.31, on mixed native stock	72	—	—	A little hair.
52*	do.	657	1 ? sp.	—	Some hair.
53†	Magunga, near Koro-gwe, 1.32	—	7 ? sp. and some debris	—	—
54‡	Arusha, 18.iii.32, on ox	41	3 ? sp.	—	Mass of hair; 3 fragments of shell, the largest 0.8 cm. ² ; 3 fragments of grass.
55‡	Engare Nanyuki, iv.32, shot off drying meat	21	8 of 2 spp.	—	Mass of hair; some amorphous fatty substance.
56‡	Engare Nanyuki, iv.32, on ox	33	6 and much debris	—	—
57‡	do. on donkey	—	—	—	— (absolutely empty).
58‡	do. on same donkey	17	—	—	Much free red blood.

* Sent by Capt. M. S. Moore, V.C. † Sent by Mr. T. A. Baldock. ‡ Sent by Mr. J. T. Purvis.

TABLE II.

Identifications of ticks by Dr. E. A. Lewis.

Specimen No.	<i>Rhipicephalus</i> spp.	<i>Boophilus annulatus decoloratus</i>	<i>Amblyomma variegatus</i>	Others
5	—	—	44	—
6	<i>R. appendiculatus</i>	56	—	—
8	do.	11	109	—
9	do.	1	4	<i>I. pilosus</i> 2
11	do.	5	—	—
12	do.	3	1	—
13	do.	5	1	—
14	do.	7	3	—
16	do.	10	—	—
19	do.	5	—	—
21	do.	11	6	<i>Hyalomma</i> sp. 5
22	do.	7	1	—
	<i>R. bursa</i>	2	—	—
25	<i>R. appendiculatus</i>	2	—	—
26	do.	7	3	—
	<i>R. bursa</i>	1	—	—

TABLE II—continued.

Specimen No.	<i>Rhipicephalus</i> spp.	<i>Boophilus annulatus decoloratus</i>	<i>Amblyomma variegatus</i>	Others
28	<i>R. appendiculatus</i> 8	—	—	—
29	do. 20	—	1	—
34	do. 3	—	—	—
35	do. 9	6	1	—
36	do. 23	6	2	—
38	do. 18	10	4	—
40	do. 5	3	3	—
41	do. 3	—	—	—
42	do. 6	1	—	—
43	—	4	1	—
45	<i>R. appendiculatus</i> 3	3	2	<i>I. pilosus</i> 1
46	do. 15	—	—	do. 5
	<i>R. simus</i> 3	—	—	—
47	<i>R. appendiculatus</i> 1	—	2	<i>I. pilosus</i> 2
48	do. 1	3	—	do. 1
	<i>R. simus</i> 1	—	—	—
49	<i>R. appendiculatus</i> 96	—	2	—
50	do. 52	—	6	—
51	do. 28	1	—	—
	<i>R. bursa</i> 1	—	—	—
52	<i>R. appendiculatus</i> 78	—	—	<i>Hyalomma</i> sp. 2
	<i>R. evertsi</i> 6	—	—	—
55	<i>R. simus</i> 4	—	—	<i>Hyalomma</i> sp. 1
	<i>R. pulchellus</i> 4	—	—	—
	<i>R. kochi</i> 4	—	—	—
56	<i>R. evertsi</i> 18	—	—	—
58	do. 1	—	—	<i>Hyalomma</i> sp. 2
	<i>R. simus</i> 7	—	—	—
	<i>R. pulchellus</i> 3	—	—	—

Summary of the Tables.

1. Ticks of all sizes and stages of development were found to the total of 2,291 in 55 out of the 58 birds examined. The average is just over 41 ticks to each bird. Of the remaining 3 birds one was absolutely empty and the other 2 contained Diptera exclusively.

2. 812 of the ticks were identifiable by species. In East Africa *Rhipicephalus appendiculatus* is the chief vector of East Coast Fever, and *R. evertsi* and *R. simus* are also implicated. *Boophilus annulatus decoloratus* and to a less degree *R. evertsi* transmit redwater and anaplasmosis. *Amblyomma variegatum* is the only known vector of heartwater in Kenya Colony.* I have tabulated Dr. Lewis's identifications accordingly. The result shows that 776, or 95 per cent., were potential vectors of disease. It is to be presumed that this proportion would hold good for the tick material that was too much macerated for identification. The 2,291 ticks found in the 58 birds may then be allocated as follows, in round numbers :—

Total of potential disease vectors	...	...	...	2,100
Potential vectors of East Coast fever	...	...	...	1,400
" " " redwater and anaplasmosis	...	...	...	200
" " " heartwater	...	...	...	500

3. Diptera, probably nearly all blood-sucking flies, had been taken by 44 birds. Several of the stomachs contained practically nothing else.

* Cf. Kenya Dept. Agric. Bull. 13 of 1931, amplified by information given by Dr. Lewis personally.

4. Other organisms, among which lice are the most numerous, form an insignificant proportion of the food. The occurrence of the Phasmids is unexpected. They were perhaps creeping in the grass in immediate proximity to a resting beast.

5. Hair occurs in the majority of specimens but in surprisingly varied quantities. Some of the stomachs with many ticks were completely free of hair—*e.g.* nos. 5, 6, 38; others, *e.g.* nos. 17 and 18, where flies preponderated, contained plenty.

6. Small quantities of blood-clots or tissue of some kind were found in 13 stomachs and free blood in one. Of the 13, 6 contained blood-clots alone, 5 tissue alone. The blood-clots were all of very small total bulk, except in nos. 22 and 31. The microscope produced conclusive evidence that most of these had been derived from ticks and were not ingested directly by the bird.* All ovoid blood-clots are suspected to be of the same origin.

It will be noted that although no. 55 was actually shot off meat the stomach contained neither blood nor ordinary tissue. In answer to my enquiry on this point Mr. Purvis, who shot the bird, has informed me that the meat had already dried fairly hard. It was however penetrated by veins of fat and he could distinctly see where the oxpeckers had been working at this softer substance.

The specimen containing the free red blood was obtained by Mr. Purvis while it was feeding with 16 others on a donkey that was in bad condition, full of sores which appeared to have been pecked, and with blood trickling down its legs.

Discussion.

The preponderance of ticks as an element in the stomachs is very marked. On the data in Table I we should probably be justified in concluding that ticks are the oxpeckers' main-stay and first preference, with biting flies an important subsidiary. It is however to be borne in mind that ticks will probably be the most resistant to destruction of all the food swallowed, and free blood the least. The absence of the latter from practically all the stomachs except those mentioned by Mr. Hood and Mr. Clark is remarkable, and it is to be regretted that we do not know how long free blood remains recognisable after being swallowed by the bird. Except in a clear case like no. 58 the possibility is always present that any free blood found has been derived from well-fed ticks that were punctured in the process of capture. As mentioned above, apparently fresh blood has been obtained in the laboratory from ticks that had been recovered from oxpeckers' stomachs and kept for weeks in alcohol. It follows that the occurrence of free blood in an oxpecker's stomach does not necessarily incriminate the bird.

A point that forces itself on one's attention in dealing with these stomachs is the small quantity of food that seems to be present. Many of the stomachs appear at first sight to be completely full, but in these cases it is nearly all hair. Even when ticks are numerous their bulk is often trifling. The 124 freshly-caught ticks in no. 49 weighed only 0.37 gm. air-dry; the 94 in no. 50 only 0.45 gm., and the scab 0.18 gm. Now the oxpecker is rather larger than an English starling, with an average weight of about 60 grams. Nothing appears to be known about the maintenance requirements of insectivorous birds, or small birds in general, but I am informed† that on the analogy of a domestic fowl's requirements it can be calculated that the oxpecker would need 0.86 gm. of digestible protein and 7.0 gm. of starch units a day. This could not be supplied by less than 56 gm. of *fresh* blood, which is almost certainly above the bird's capacity even if it could be obtained. It is clear from the state of the ticks in the stomachs that the oxpecker is capable of digesting them completely, so that their fats and protein would become directly available. But, as

* The idea that congealed blood of this kind might be associated with partly digested ticks occurred independently to Mr. Purvis, but he has not had facilities for verifying it.

† I am indebted to Mr. M. H. French, Biochemist at the Veterinary Laboratory, Mpwapwa, for the technical particulars.

indicated above, the amount of nutriment available from that source would appear to be small. Mr. French suggests that supplementary sources of food may be the fatty exudations of the sebaceous glands with which the hair swallowed would be well greased. Scurf was thought to be another possible supplement. But although it should be identifiable under the microscope, it was never noted, and efforts to scrape an appreciable quantity off the hides of cattle met with no success. A further suggestion is that a feeding tick gets rid of some proportion of the water in the blood, so that what the oxpecker gets from the tick is a more concentrated form of nourishment still. However, these are unsupported speculations. The fact remains that it is not apparent how an oxpecker "keeps itself going."

As regards the bird's alleged predilection for feeding directly on the blood and tissue of the host-animal, there appears to be little satisfactory field-evidence that the oxpecker itself starts an excavation for the purpose of feeding. That it avails itself of any opportunities presented to it by sores or wounds is certain. The evidence is, however, that where an animal can be looked after and any abrasions on it protected, the oxpecker is not to be regarded as a nuisance. In fact the bird by consuming weakening parasites is capable of doing more good than harm.

In the matter of infectious diseases it appears that the oxpecker is capable of carrying rinderpest, anthrax and nagana (trypanosomiasis) by mechanical means, especially when it can fly direct from an open wound on an infected animal to an open wound on another. The mechanical transmission of these diseases is, however, a disability which it shares with the stock-parasites, and especially the blood-sucking flies, which have been demonstrated to contribute largely to its diet. It is probable that the birds' potentialities for evil in this respect are off-set by the reduction in effects in the numbers of the invertebrate vectors.

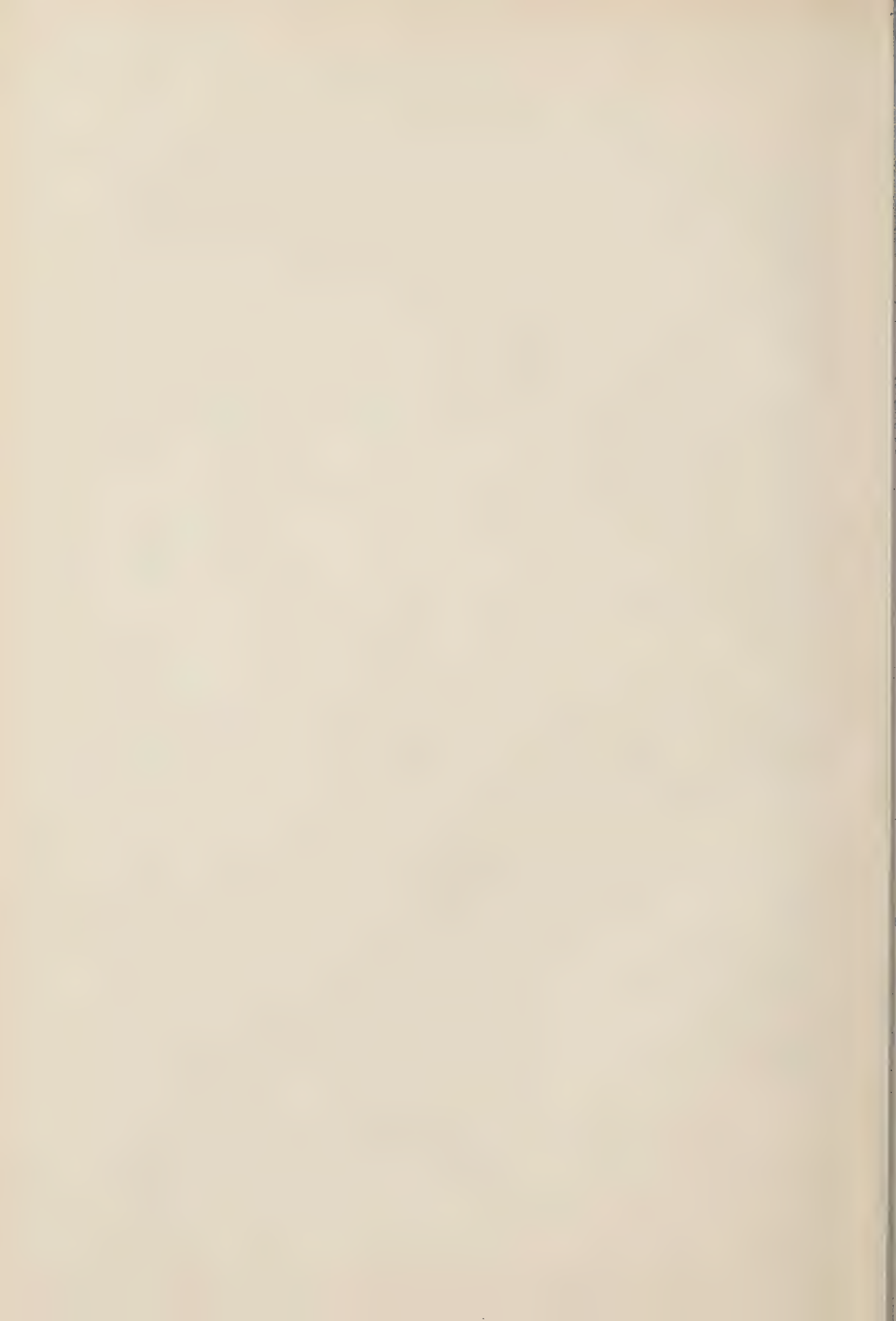
Conclusions.*

The suggestion that the red-billed oxpecker does not eat ticks is disproved. Ticks and other blood-sucking parasites of stock form an important, and probably the major, part of its diet. The evidence that this oxpecker starts holes in the hides of stock for the purpose of feeding on tissue is poor, although it is certain that it takes advantage of the presence of sores and abrasions. Against the damage done by the oxpecker must be set the benefit it confers by the removal of invertebrate parasites. But the damage by the birds tends to be greater in the herds that are in bad general condition.

As regards its influence on disease transmission the oxpecker's potentialities for evil in mechanically transmissible diseases may be offset by its consumption of invertebrate vectors. In respect of the group of diseases that depend for their dissemination on ticks, the oxpecker must exercise a powerful controlling influence.

Taking all the bird's activities together it appears that the balance inclines more in its favour than has been generally admitted. It is far from being an "unmitigated nuisance and pest." Where a herd is in good physical condition, but exposed to attack by ticks, the presence of oxpeckers might be expected to be definitely of value.

* Conclusions at this stage of our knowledge must be mainly tentative. Wide variations in the effect of oxpecker activity could doubtless be demonstrated at different places and on different dates.



THE VIRUS OF RINDERPEST AND ITS RELATION TO *GLOSSINA MORSITANS*, WESTW.

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The earliest known cases of the coincident disappearance of tsetse-fly from an area affected with rinderpest occurred in the Transvaal and Rhodesia in the early nineties of last century (Stevenson Hamilton, 1911 and 1912). There is no doubt that the fly either decreased or entirely disappeared from various districts in these two territories following the great rinderpest epizootic in the wild fauna. A satisfactory explanation has not yet been given to account for this remarkable phenomenon.

Fuller (1923) in a most interesting historical review of the tsetse position in the Transvaal and neighbouring territories points out that although there had been a gradual shrinkage of the fly over a period of some years, the disappearance of *Glossina* from the Eastern low country of the Transvaal can be definitely attributed to the rinderpest epizootic. He further states (p. 347) that "it has been shown experimentally that disease-laden blood does not militate immediately against the fly." No reference is given in support of this statement, and I am unable to trace any published experimental evidence in this connection, with the exception of Duke's (1919) work, which is referred to later.

Howard (1910), discussing the tsetse position in the Inhambane and Lourenço Marques districts of Portuguese Territory, states that after rinderpest passed over South Africa the fly began to disappear and that they had been unable to locate a single tsetse-belt in that portion of the country.

In Uganda similar occurrences have been recorded. Duke (1919) gives a detailed account of the disappearance, or at all events great diminution, of *Glossina morsitans* from the Masindi fly-belt following the rinderpest epizootic of 1917-1918. Numerous surveys were made of the country from 1921 onwards, and in 1927 this particular area was finally surveyed for fly by Mr. Kennedy, of this Department, during the rains and by myself in the dry weather. Every effort was made to locate the presence of tsetse. Bait cattle accompanied by either of us and by trained fly-boys covered the whole of the country which was previously infested without revealing a single *Glossina*. The areas mentioned by Fiske (1914) and Duke (1919) were especially dealt with, and native evidence as to the general history of the area previously infested was carefully sifted and investigated. Subsequently, in a conversation with Miss M. Robertson of the Lister Institute, who worked in this area in 1912, further areas then infested were found to have been covered by our survey. Some 10,000 head of cattle now graze in this former fly-belt, and no serious incidence of trypanosomiasis has been recorded since the restocking of the denuded areas began in 1928.

Simmons (1929) mentions a recedence of *Glossina morsitans* towards the River Kagera following the rinderpest epizootic of 1919 in South Ankole, Uganda.

In 1925 rinderpest invaded the West Nile District of this Protectorate, and a most marked diminution of tsetse occurred in the Rhino Camp road area following the mortality in the susceptible game. This occurrence was subsequently investigated by Kennedy (1929), who noted that the fly continued to be scarce in this area. The game, however, had not recovered its previous numbers, mainly owing to increased traffic on the road and heavier shooting.

In other localities, which had been visited in 1926, there was no apparent decrease in the fly density, although rinderpest had been recorded in them.

At the present time *G. morsitans* is extremely scarce, and it is the exception rather than the rule to see one.

It will be seen then that the classical cases of the Transvaal and Rhodesia are not isolated records of apparent disappearance or marked diminution of *Glossina morsitans* following an epizootic of rinderpest, and the examples seen in this Protectorate suggest strongly that there is a definite relation between the two incidents.

Duke (1920) in his paper examines the available and rather meagre evidence bearing on the interrelation of game, *Glossina* and rinderpest, and suggests three hypotheses which, if proved, would account for the disappearance of the fly. He carried out certain experiments in this direction to determine what effect the rinderpest virus per se had on *Glossina*. Unfortunately *G. morsitans* was not available in large enough numbers and *G. palpalis* was utilised for this experimental work. Whilst it was obviously of value to determine the effect of the rinderpest virus on any member of the genus, there is no record of any disappearance of *G. palpalis* with the passage of rinderpest.

As the result of his investigations he recorded that so far as this species was concerned rinderpest virus in blood did not affect it, and he considered that a combination of circumstances affecting the food supply, together with the destruction of breeding-places by unusually complete burning, accounted for the marked diminution of the fly.

Rinderpest is definitely pathogenic to certain species of game and, so far as Uganda is concerned, the order of susceptibility has been found to be: Buffalo, eland, warthog, and then pigs, bushbuck, sitatunga and cob.

The object of this paper is to record experiments carried out to determine the effect of rinderpest virus on *Glossina morsitans*.

The presence of rinderpest in the game areas of South Ankole, which, as previously mentioned, are also infested by *Glossina morsitans*, presented an opportunity to study the question of the relationship, if any, between rinderpest and the fly.

Since experimental clearing operations were being carried on in this fly-belt at the time, it was impossible to estimate any effect the rinderpest might have had on the fly density of the whole area, but *G. morsitans* in adequate numbers were available for detailed investigation.

The following programme was arranged :—

1. To determine what effect the virus of rinderpest has on *G. morsitans* when the later is fed on animals affected with the disease.
2. To determine whether the blood of animals infected with rinderpest interferes in any way with the normal reproduction of the fly.
3. To make observations on the co-relation of *G. morsitans* with animals infected with rinderpest.

So far as is known, there is no essential difference between rinderpest in cattle and in wild game, but as it is the disease in the latter which has been coincident with *G. morsitans* disappearance or diminution, it seemed desirable to work with a game strain of the disease, and I was fortunate enough to recover the virus from a naturally infected eland.

Blood and a saline suspension of spleen were inoculated into a calf and the virus propagated in cattle of high susceptibility throughout the period of the investigations. The death rate of such cattle was 100 per cent., and rinderpest was confirmed in each case by post-mortem examination.

The flies were kept in captivity three to seven days before being used in an experiment in order to eliminate as far as possible the error due to natural mortality following capture. They were then transferred to lamp-glasses (15 in. by 3 in.) covered at either end by mosquito netting of wide mesh.

An average of 10-15 flies with a sex ratio of 1 ♂ to 5 ♀ were kept in each glass. For breeding experiments trays of soil from natural breeding-sites were placed below the lamp-glasses containing the flies. The soil was approximately $\frac{1}{2}$ in. in depth.

In each experiment flies were divided into two groups, one group being fed on rinderpest animals and the other on healthy control animals. It was essential of course to have standardised conditions for each series of flies. All groups were kept in lamp glasses under identical conditions. They were fed at the same time, once every twenty-four hours, and they were allowed to have five minutes contact with the animal on which they were feeding.

Experiment 1. *To determine the effect of feeding G. morsitans on cattle infected with a "game strain" of rinderpest.*

No. of expt.	Flies fed on cattle infected with rinderpest			Flies fed on healthy cattle		
	No. of flies fed and sex	Period of feeding	No. of Flies remaining at end of expt.	No. of flies fed and sex	Period of feeding	No. of flies remaining
1	100♂	10.iii.31 to 31.iii.31 (21 days)	46	100♂	10.iii.31 to 31.iii.31 (21 days)	45
2	100♂	17.ii.31 to 25.iv.31 (36 days)	36	100♂	17.ii.31 to 25.iv.31 (36 days)	44
3	100♂	1.iv.31 to 9.v.31 (39 days)	32	100♂	1.iv.31 to 9.v.31 (39 days)	38
4	40♀	1.iv.31 to 9.v.31 (39 days)	17	40♀	1.iv.31 to 9.v.31 (39 days)	16
5	162♀	8.v.31 to 10.vi.31 (34 days)	27	158♀	8.v.31 to 10.vi.31 (34 days)	23
6	100♀	23.v.31 to 10.vi.31 (18 days)	60	100♀	23.v.31 to 10.vi.31 (18 days)	64

The flies fed freely on the rinderpest hosts at all stages of the disease from early pyrexia to within an hour of death, which is interesting in view of the unpleasant odour so commonly observed in fatal cases of rinderpest.

Experiment 2. *To determine the effect of feeding pregnant Glossina morsitans with rinderpest virus.*

Eighty female *Glossina morsitans* were selected as being pregnant. The majority were obviously so, but in the small minority their state could not be ascertained definitely. The flies were divided into two groups—one division being fed on rinderpest animals and the other on healthy controls. The jars containing the flies were suspended over separate trays of soil for the trapping of larvae and subsequent pupation.

No. of flies ♀	Type of animals on which fed	Period of feeding	No. of pupae collected during this period	No. of flies which emerged from these pupae		
				♂	♀	Total
40	Animals infected with rinderpest	39 days	15, plus 4 which were destroyed by accident	6	7	13
40	Healthy animals	39 days	21, plus 1 which was destroyed by accident	8	9	17

Experiment 3. *To determine whether there is any appreciable difference between the emergence rate of pupae collected in an area where the wild fauna had been and was dying of rinderpest and in an area where the game is healthy.*

The "rinderpest area" pupae were collected by Mr. J. T. Kennedy in the Nakivali area and forwarded to Nsongezi. In the region of the Nakivali lakes, where that officer was working, game was found to be dying of the disease early in February, and fresh carcasses of susceptible animals were still being found in June. Buffalo, eland, bushbuck, warthog were the animals affected.

The "healthy area" pupae were forwarded by Mr. R. J. Simmons from the Kakitumba area, some fifty miles from Nakivali, where no rinderpest existed either amongst cattle or game, of which the commonest species in that section was eland.

No. of pupae	Locality in which the pupae were collected	Date of collection	No. of flies emerged from field pupae—%		No. of pupae collected in the laboratory from these flies
			*		
34	Healthy area	April 4th	21	61.7	3
26	Healthy area	April 8th	14	53.8	1
61	Rinderpest area	March	30	49.2	—
114	Rinderpest area	April	75	69.9	3
128	Rinderpest area	May	57	—	not completed

As the flies emerged, they were put into separate jars with the sex proportion 1 ♂ to 5 ♀ and were placed over trays of soil in order to obtain if possible a second generation of pupae and flies. The results of this pupation are set out in column 6 above, but unfortunately owing to a transport accident they were not completed.

The flies which emerged from "rinderpest area" pupae were fed entirely on rinderpest infected animals, the "healthy area" flies on healthy animals.

Experiment 4. To determine what effect the virus of rinderpest has on the fertility of *G. morsitans*.

It was decided to carry out these experiments in large insectaries erected in the open and in the locality where *G. morsitans* constantly exists, as it was felt that the most likely conditions under which the flies would breed were those approximating most closely to the natural environment. The interiors were arranged to resemble so far as possible a natural breeding-site, with fallen logs, rocks, bushes, etc., and varying degrees of shade. They did not prove a success, however, for during a period of three months some 1,500 ♀ and 300 ♂ were released in each of two insectaries, one for flies to be fed on rinderpest infected animals and the other for the feeding on healthy controls.

Only seven pupae were collected from the rinderpest cage and not one from the healthy enclosure. The flies appeared quite healthy and lived as long as in the laboratory. It was, however, impossible to check numbers accurately.

More success was obtained in the laboratory using lamp-glasses over soil as described above, and the results are tabulated below :—

No. of flies	Type of feeding	Period of feeding	Apparently healthy pupae collected during this period and remarks
158 ♀ 31 ♂	Healthy cattle	34 days	38 ; 6 abortions
162 ♀ 32 ♂	Rinderpest cattle	34 days	46 ; 4 abortions
100 ♀ 20 ♂	Healthy cattle	18 days	17 ; 1 abortion
100 ♀ 20 ♂	Rinderpest cattle	18 days	17 ; 1 abortion

Obviously pregnant females were not used in this experiment, but it is reasonable to assume that a certain proportion would be in the early stages of pregnancy before they were put into jars. Pupae were collected daily up to the last day of the experiment, *i.e.*, the 18th day and the 34th respectively, and therefore assuming the gestation period to be approximately 14–15 days (Kinghorn, 1912), it was taken that fertilisation had occurred in captivity.

It was noted that in many cases the pupae collected in the laboratory under artificial conditions appeared to be smaller than the natural field pupae, but slightly heavier.

No suitable instrument was available for measuring them, but the following average weights were recorded :—

No. of pupae	Locality of pupae	Average weight
42	Collected in the field	0.19 grammes
21	Laboratory pupae collected from flies fed on rinderpest blood	0.23 grammes
21	Laboratory pupae from flies fed on healthy animals	0.22 grammes

Discussion.

From the foregoing protocols it is impossible to obtain any evidence that rinderpest virus, as it exists in the peripheral blood of infected animals, in any way affects *Glossina morsitans*, either directly or from the point of view of reproduction.

Some of the experiments, especially those in connection with reproduction, were not entirely satisfactory in that a number of the female flies used must have been in a pregnant condition at the commencement of the experiment, but the evidence at all events indicates that rinderpest virus does not directly affect that condition.

The flies both in the containers and free in the insectaries fed greedily on both rinderpest and control animals, even when the former were in an advanced stage of the disease and in a marasmic condition.

Twenty-one animals were used to propagate the virus, and in each case the disease ran a typical course and its presence was confirmed by post-mortem examination.

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THE BREEDING OF *ANOPHELES MAURITIANUS* IN PALESTINE.

By Z. SALITERNIK, *W*

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The Kurdani stream starts about 15 kilometres to the south-west of Acre. It is fed at its source by a series of springs that flow in narrow creeks (20–30 centimetres) which ultimately unite into a stream 1–5 metres wide. This stream widens as it receives waters from other springs, ultimately forming a stream the average width of which is 20–30 metres. It proceeds for several kilometres until it becomes the wide Namein River, which flows into the Mediterranean Sea near Acre. The width of the river changes during various months of the year in connection with the winter rains and the dry summer months. The numerous unregulated springs and the flooding of the river give rise to a series of swamps along the entire length of the stream. These swamps are covered with a rich plankton, especially *Potamogeton*, Algae and *Chara*. Hitherto the *Anopheles* found in this area have been *A. elutus*, *A. hyrcanus* and *A. algeriensis* (especially in the springs of Kurdani). These are found mostly at the edge of the swamps, in places covered with horizontal vegetation. *A. sergenti* and *A. superpictus* have also been found in small numbers in the ditches of the Kurdani springs and in small collections of waters along the banks of the river. *A. multicolor* is sometimes found in the mouth of the Namein River near the sea.

In 1929 the possibility that *A. mauritanus* might breed in the Kurdani-Namein River was suspected, when in June a female *A. mauritanus* was caught by me, together with 2,600 *A. elutus*, in one of the cellars in a house located in the heart of the Namein swamp, about 3 kilometres from the point where the river empties into the sea. Previously, Barraud (1920) reported the breeding of this species in the swamps of the Auja and Kishon Rivers, but since then there has been no confirmation of his findings. Buxton (1923) writes, "I have never taken it and I know of no records other than Barraud's."

Beginning with 1930 the region of the river has been visited by me regularly, and in July of that year, amongst other larvae and pupae, there were also taken two pupae from which *A. mauritanus* emerged. It was not, however, until July 1932 that I succeeded in finding a concentrated breeding-place of this species and studying the conditions favouring its propagation.

On 24 July I found *A. mauritanus* breeding in only one place in the Kurdani River. This was a small pool on the bank of the river which dried up with the fall of the waters during the summer months. The point where breeding was found was about one metre from the bank of the river, in a pool 3 by 5 metres in area, overgrown by reeds and covered by a growth of algae and other aquatic vegetation. In the course of five inspections during the month of August larvae of this species were regularly found, always associated with those of *A. hyrcanus* and *A. algeriensis*. With the drying up of the pool the larvae gradually decreased and ultimately disappeared. During these inspections both banks of the river were examined for a distance of two kilometres in both directions from the point where this species was breeding, but no other breeding-places were discovered. However, during September, with the progressive fall in the level of the water, several such places were found; five of them were within 100 metres of the first breeding-place (5–7 larvae to a dipping, with *A. mauritanus* 20–50 per cent., and the remainder 80–50 per cent. *A. hyrcanus*) and a sixth two kilometres down stream (3–4 larvae to a dip, with *A. mauritanus* constituting 5 per cent. and the remainder *A. hyrcanus*).

The characteristics of the breeding places were:—Temperature of the water, 2°–27°C.; depth of the water, 20–70 centimetres. The pools were stagnant and overgrown, containing still, clear water, connected with the stream, but not affected by its flow. The breeding occurs near the reeds, amidst the aquatic vegetation, partly in sunlight and partly in shade. The algae found in these breeding-places were *Ricchia fluitans* and *Cladophon* sp.

Chemical analysis of the water (made in the laboratory of the Nesher Co.) gave the following results:—

pH	...	...	...	...	750	
Cl	...	...	...	...	608.96	mg. per litre
NaCl	...	...	...	...	974.34	" "
SO ₃	...	...	...	...	29.34	" "
CaSO ₄ 2H ₂	...	...	...	...	64.25	" "
MgO	...	...	...	...	53.7	" "

Larvae of *A. mauritanus* were never found alone, but always in association with *A. hyrcanus*. The larvae of these two species are difficult to differentiate. The chief point of distinction is in the innermost shoulder hair, which is simple in *A. hyrcanus* and branched in *A. mauritanus*. The larvae and pupae are very resistant; for instance, in September with the air temperature at 48°C., and active shaking for two hours due to the movements of a wagon over a bad road, the larvae arrived at their destination in good condition and continued to develop excellently under laboratory conditions.

At a distance of 10–100 metres from the five main breeding-places there is an old water-mill with a storehouse, stable, cellars and a cave. This place is inhabited by an Arab family, and passing travellers with their horses, donkeys and camels often spend the night there. These places serve as excellent resting-places for *A. elutus*. However, although this is the only house within a radius of 5 kilometres from the breeding-places of *A. mauritanus*, I have never in all my searchings there found specimens of this species. It is apparent, therefore, that this mosquito is not a house visitor and that the previous discovery (1929) of a single *A. mauritanus* in a cellar was an isolated exception. On one occasion in September 1932, out of eight *Anopheles* caught outdoors, towards evening, as they came to feed, four were *A. mauritanus* and the others *A. hyrcanus*. On 9th September at 11.30 a.m., while amongst a thick growth of reed, I caught a female *A. mauritanus* attempting to feed on my hand.

The specimens which emerged from the larvae brought from the field did not thrive in captivity. Only a few mosquitos took one or two blood meals, but even these died on the third or fifth day.

Summary.

A description is given of the detection of an active breeding place of *A. mauritanus* in the Kurdani River, near Acre. This species was first reported by Barraud in 1920 as breeding in the swamps of the Kishon and Auja. Since that time neither Buxton nor the other workers in Palestine have been able to find this species. It is conceivable that the reason for the failure is due to the fact that the larvae closely resemble those of *A. hyrcanus* and that like it, the adult is a swamp feeder and not a house visitor.

THE BIOLOGICAL CONTROL OF THE WEED *CLIDEMIA HIRTA*, D. DON., IN FIJI.

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The plant *Clidemia hirta* belongs to the natural order Melostomaceae. It is of shrubby growth, with a hard tough stem and produces quantities of dark purple berries, filled with minute seeds. These berries are much relished by certain birds, which feed upon them and distribute the seeds. The leaves are covered with fine hairs and the plant is not eaten by stock.

The plant is a native of the West Indies, Central America and the Northern portion of South America. It is supposed to have been introduced into Fiji from British Guiana at some time prior to 1890. That this was the origin of the plant is supported by slight differences observed by the writer in the foliage of the Trinidad, Panama and British Guiana forms of the plant, the Fijian one closely resembling those of the last named country.

In Fiji the plant was first observed along the fences of paddocks in the Waimanu Valley, whence it spread with great rapidity, quickly becoming a weed of major importance. By 1919, when the writer arrived in the country, thousands of acres were covered with it to the exclusion of almost all other growth. On good soil it formed a stand five or six feet high, through which the cattle were only able to keep open narrow paths. Not only did it rapidly occupy the open grass lands, particularly the rich dairying and fattening country, but it thrived almost equally well under the shade of coconut and rubber plantations, leading to loss of many fallen nuts and entailing greatly increased weeding costs.

On the dry side of the Islands its spread was less rapid and cultivation proved fatal to it. Cultivation was, however, impracticable and often not even possible in old coconut plantations or permanent pastures.

As soon as the danger of the new introduction was realised, Mr. C. H. Knowles, then Superintendent of Agriculture, took steps to have the plant identified and to ascertain its native habitat.

There is no doubt that it was the presence of certain introduced birds, such as the Indian mynah, which led to the very rapid spread of the weed in Fiji. Many other agents, however, also assisted, including the native Silver Eye (*Zosterops flaviceps*) and probably many doves and pigeons, and it is said that even the mongoose found the berries palatable.

The plant suffered little from disease and produced great quantities of fruit. Mites, mealybugs, Aphids and a *Lecanium* scale attacked it, as did a leaf-spot disease, but these generally had little effect, except where the plants were becoming aged.

In November 1919 reports were received that the plant was dying out in certain portions of its original habitat at Waimanu. This was investigated by the writer, in conjunction with the Superintendent of Agriculture, Mr. Knowles. It was then found that on some of the poor red hill-lands a nematode worm of the *Heterodera* group was attacking the roots, leading to die back, poor fruiting and even replacement of the weed by other plants. This condition was, however, confined to a very limited type of country and, generally, the weed continued to flourish, even invading the forests. In view of the hopelessness of controlling the weed economically it was decided to enquire whether in any portion of its range insect agencies were known to exercise an appreciable effect upon its growth or spread. With that objective,

correspondence was opened about 1920 with Trinidad, Jamaica and British Guiana. The writer also prepared drawings of the plant and forwarded dry material to Trinidad for comparison with the local species recorded under the same name.

As a result of the attention thus called to it, a number of plants of *Clidemia hirta* were dug up and planted in the grounds of the old Experimental Station at St. Clair in Trinidad, and upon these Mr. F. W. Urich, then Government Entomologist of that country, discovered the thrips which now bears his name. No great value was at the time placed upon the controlling effect of this insect, and no further action was taken until 1927, when Mr. T. H. C. Taylor, who was visiting Trinidad in connection with coconut work, made a "preliminary study of the plant . . . with a view to finding some controlling factor which might be applied to Fiji" (Council Paper, Fiji, No. 14, 1928).

This officer expressed a favourable opinion of the value of the thrips discovered by Urich, and it was decided to investigate the matter further.

In 1928, Mr. W. Cook, a student of the Imperial College of Tropical Agriculture, made a study of the insect, carrying out a series of starvation tests upon economic plants and making a number of observations upon the life-history and natural enemies of the insect. As a result of these tests this Entomologist came to the conclusion that the insect was "specific with regard to its food-plant *Clidemia hirta*, and if introduced would not attack any other plant in Fiji." As a result of these two reports the writer was despatched to Trinidad to endeavour to introduce and establish the insect in Fiji. Whilst there, further investigations concerning the control of the plant in that country were carried out.

It was found that the genus *Clidemia* was represented by a number of species in addition to *hirta*, the commonest being *pustulata*, *dentata*, *neglecta* and *rubra*. None were weeds of any importance, although *pustulata* occasionally became abundant, and the conclusion was arrived at that the factor holding them in check was a biological one. At the same time since *Liothrips urichi* was confined to *Clidemia hirta* and was not universal even on that plant, it was felt that other and probably more powerful agencies were at work. Such agencies were discovered in a number of insects attacking the buds, flowers and seeds of all the members of the genus. The most abundant of these were certain gall-forming Chalcids which attacked the seeds, causing malformation and hardening, frequently with premature falling.

Next in abundance, and possibly of more importance, was the larva of a Cosmopterygid moth, *Mompha trithalama*, Meyr., which entirely destroyed the contents of the green berries.

Another moth larva, that of *Carposina bullata*, Meyr., with similar habits was also abundant.

Other caterpillars attacking the berries were *Compsolechia seductella*, Walk., *Hoplophractis haptachalca*, Meyr., and *Piesmopoda* sp.; and the larvae of a Lycaenid butterfly, *Siderus leucophaeus*, Hb., destroyed the young flower-heads.

The above formidable array by no means completed the list of insects attacking the fruiting bodies of the plant, but these or similar insects were found to be present upon all other species of *Clidemia* and fully accounted for the very small number of mature fruits produced by these plants as compared to those present upon *C. hirta* in Fiji.

Further it was observed that bare damp exposed areas in the bush, which in the wet season were covered with moss and small plants and seedlings, showed only very few specimens of any species of *Clidemia*. Such areas in Fiji would produce an almost complete sward of *C. hirta*, thus forcing the conclusion that in Trinidad this plant and also the other members of the genus were held in check biologically and that such biological control was principally by the action of seed-destroying agencies.

When Urich discovered *L. urichi*, he also found that it was subject to the attacks of a Cecidomyiid, a Reduviid and a Chalcid. Subsequent workers failed to observe the last two and concluded that the effect of the first was negligible. The matter was one of importance, since if the thrips itself suffered considerably from enemies, the elimination of these should greatly increase its value, so that particular attention was given by the writer to this point.

It was then found that *Liothrips* suffered considerably, not only from the three insects enumerated above, but from several others, the existence of which had not been suspected. The most important was undoubtedly the Cecidomyiid, *Thripsobremia liothripsis*, Barnes, which was estimated to destroy from 30 to 40 per cent. and was possibly specific. The Reduviid, *Heniarthes flavicans*, F., was a somewhat scarce predator, and the Chalcid was only met with on one occasion.

The most important of the newly discovered enemies was a predatory mite, *Hyletastes* sp., which destroyed both nymphs and adults. Another bug, an Anthorcorid, *Macrotracheliella laevis*, Champ., was observed sucking eggs and pupae and, although uncommon, was capable of destroying numbers. Jumping spiders and Syrphid flies also took a toll. It will thus be seen that *Liothrips urichi* had many and powerful enemies, giving it a greatly increased potential value if they could be eliminated.

In view of the specific character of the attacks of *Liothrips urichi*, no hesitation was felt in introducing this insect into Fiji as a first choice, although in Trinidad undoubtedly it was not the most important of the agencies attacking the plant. An additional factor in its favour was that when heavy its attacks caused complete die-back of all young growth and not reduction of seed production only.

The insects were conveyed to Fiji upon growing plants of *Clidemia hirta* in large cages 3ft. \times 3ft. \times 3ft. An effort was made to obtain a pure stand of the insect by eliminating its enemies at the Trinidad end, but this failed owing to lack of facilities for fumigation of the food-plants in that country.

Difficulty was experienced in transport owing to the rapid increase of the thrips destroying its food-plant and also to an infestation of mealybugs, which were difficult to hold in check. On arrival in Fiji the cages were placed in an insect-proof insectary, whence they were removed to another chamber, where adults only were carefully removed by hand and placed upon growing plants of local origin. After the removal of about 20,000 thrips, the food-plants were first fumigated and then dumped, with all soil, into the sea. Of the introduced material a portion was liberated at once and the balance held for breeding, colonies from the latter source being distributed throughout the affected areas during the whole of 1930.

The first colonies were released in Fiji in March 1930, but unfortunately the season proved very unfavourable, extremely dry conditions following. By January 1931 very little progress had been made, only a few specimens were to be observed, all within 300 or 400 yards of the points of liberation. With the advent of heavy rains followed by a long period of warm moist conditions the insect made rapid progress, showing a surprising ability to cross several miles of sea or jungle, so that 18 months later most of the colonies had linked up. The biggest jump was at Buca Bay on Vanualevu, to reach which point the insect must have travelled 30 miles in less than two years or crossed nearly 20 miles of ocean. That such migration is not absolutely without direction is shown by the fact that isolated plants one mile from any infected area have almost invariably been found and colonised by the insect.

The first result of the establishment of *Liothrips urichi* in Fiji was that over wide areas where *Clidemia hirta* was growing luxuriantly the terminal shoots, which were being attacked died back and growth was arrested. This check on the growth of the plant enabled rival weeds to outgrow it and commence to choke it, leading to

further checking of the vitality of the plant. Such weeds which overgrew the *Clidemia* were *Micania scandens*, *Mimosa pudica* and Para grass, the last two good cattle feeds and the first also eaten by cattle when wilted. In many cases small marked clumps of the *Clidemia* were actually destroyed, a tangled growth of the above three plants replacing it. In larger areas the work of the *Micania* was of more importance, and by August 1932, some 27 months after liberation, many hundreds of acres which had been a solid sea of the weed 6 feet high were, on Taveuni, changed to a vast area of *Micania*, perhaps averaging 3 feet from the ground, under which lay the dead or dying skeletons of the weed, with only here and there a few shoots showing but not producing seed.

Where cattle are running, selective feeding is necessarily taking place and such plants as Para grass and *Mimosa* would have little chance to overgrow the weed, and it was consequently necessary to cut back or grub the plant in such areas. The effect of cutting back seems in most cases to have been sufficient, *Liothrips* proving an efficient check upon the regrowth of the weed.

Liothrips urichi in Trinidad showed a marked aversion from shade, and it was not anticipated that it would enter the forests. In many cases, however, in Fiji, probably owing to the much denser thrips population due to elimination of natural enemies, the insect has penetrated miles into the jungle, colonising heavily those clusters of the weed receiving even only a moderate amount of light. On Taveuni also and elsewhere, it was observed that isolated plants growing beneath coconuts and other trees were heavily attacked. The insect requires young succulent growth, so that very old plants of the weed are but lightly attacked, and in times of drought its work is also checked.

When *Micania* or other plants overgrow the weed and cause defoliation, there is a migration of the thrips from these plants to more succulent growth. This sometimes enables the weed to send out new shoots for a time before being rediscovered by the insect; this is, however, only temporary. Nevertheless, despite the above limitation, the thrips can be definitely said to have brought the weed under control over large areas, not by directly killing it, but by so inhibiting its growth that it was no longer able to compete with the surrounding vegetation. It is then replaced by such plants as are dominant in the district, such as *Mimosa*, Para and other grasses in the paddocks, *Micania* on the coconut estates, and by the roadsides such weeds as *Solanum torvum*, *Stachytarpheta jamaicensis* and *Mimosa pudica*.

It is impossible to be certain as to the future, but the indications are that eventually a balance will be struck in which sufficient *Clidemia* plants will survive to enable a light infestation of *Liothrips* to maintain itself, any further increase from time to time of the weed leading to an increase in the thrips followed by a decrease in the food-plant.

A SIMPLE METHOD OF COLLECTING THRIPS AND OTHER INSECTS FROM BLOSSOM.

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During the course of an investigation having as its object the control of *Thrips imaginis*, Bagnall, a pest of deciduous fruit blossom in Australia, it has been found necessary to make numerous counts of the number of these insects found infesting various flowers. These counts are made for two purposes, the principal one being the determination of the effect of attempted control measures. In addition, counts are taken every day throughout the year for the purpose of following the seasonal fluctuations of the numbers present in the field.



Fig. 1. Apparatus for collecting thrips.

At the beginning of the investigation, flowers were picked, placed in closed cardboard cylinders and taken into the laboratory. Each blossom was then examined separately for thrips, the insects being captured by means of a moistened camel-hair brush, with which they were transferred to a small dish of 70 per cent. alcohol. This method was slow and not particularly dependable, as on hot days when the thrips were active, as soon as a flower was placed on the laboratory bench, numbers of insects would leave it and make off in all directions, even taking to flight.

As a result of the unsatisfactory nature of the procedure described above, an apparatus has now been devised which is saving both in time and patience, and gives reliable results (fig. 1). It consists of a glass cylinder 5 inches in diameter

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and 10 inches high. The top is closed with a close-fitting lid. The bottom is open, the lower edge being evenly ground. In the centre of the inside of the lid is fixed a cotton wool pad (*p*) supported by a ring of plasticine. Two inches from the bottom is a perforated zinc plate, which is removable. It is held in position by three slightly projecting curved portions of the plate. The outside of the lid and the top 8 inches of the cylinder are covered with black paper (from A to B). When in use the jar is placed on a piece of white paper, which rests on a sheet of cork. A bench lamp is placed with the light directed on the lower uncovered part of the cylinder. A few drops of turpentine are then placed on the cotton wool pad, and the blossom placed in the cylinder. From 15 to 30 minutes later all the thrips will be found dead on the paper. Any other insects that were present in the blossom will also be on the paper, but larger ones will be only temporarily stupefied. The best results are obtained when the flowers are dry ; if they are wet, a certain proportion of the thrips will adhere to the side of the jar.

Turpentine has proved the most satisfactory of the various substances tried, since in addition to serving as a thrips repellent, its lethal action is slow, thus permitting the insects to leave the flowers and go away from the source of the smell towards the light, before dying.

It is felt that this apparatus or an adaptation of it may prove of assistance to other entomologists. Its value to the author can be judged when it is stated that between two and three thousand thrips may occur in a single rose during an epidemic of these insects !

A METHOD FOR OBTAINING SAMPLES OF THE POPULATION OF COLLEMBOLA (SYMPHYPLEONA) IN PASTURES.

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In our investigations on *Smyntaurus viridis*, L., a study has been made of the population of this species, in an area of lucerne, at intervals of three and four days throughout the season.

The density of the population of the species in a favourable pasture is markedly affected by the relative abundance of certain food-plants, especially leguminous species and particularly clovers such as subterranean clover (*Trifolium subterraneum*) and lucerne (*Medicago sativa*).

The activity of the insect is intimately associated with the moisture of its environment, and the moisture content of the surface soil is one of the most important factors affecting the environmental conditions.

Considering the habits of the insect, it was felt that the sweeping method would not give a reliable record of the total population in a given area of pasture. A sample obtained by sweeping with a net does not include individuals on or near to the surface of the soil. The relative proportion of individuals situated on or near the soil surface and those situated further up the plants varies considerably from time to time, according to the meteorological conditions, the growth of the herbage and the moisture content of the surface soil. It was necessary therefore to devise a simple method by means of which a more accurate record of the total population in a given area could be obtained.

The aim was to obtain a record of the population of *S. viridis*, but certain other associated species of Collembola were also recorded, e.g. *Katianna australis*, Womersley, and *Isotomurus palustris*, Müll. It is thought that the method can be used for other insects in pastures, and as it may be of interest to workers on similar problems a brief description of it is given.

The apparatus consists of a cylinder of convenient size (our cylinders were 10 ins. high by $6\frac{1}{2}$ ins. diameter), made of 14-gauge galvanised iron, to which suitable handles are fitted (fig. 1, *a*). The bottom of the cylinder is bevelled to form a sharp, cutting edge. The top of the cylinder is covered with fine mesh brass gauze. Two lids are provided which fit snugly on the top and bottom of the cylinder. A spade having a sharp, flat blade is required.

The method of sampling is as follows: The open end of the cylinder is placed at random on the pasture and forced into the soil to the required depth (about half an inch) by a rotary movement of the cylinder. The section of pasture and soil enclosed is now cut through, below the cylinder, with the spade, and the cylinder with its contents removed on the spade. The lids are placed on the cylinder, which can now be removed to the laboratory for separation of the insects.

To obtain a representative sample, any convenient number of similar cylinders may be used. We used three on each occasion that samples were taken. They were housed in a case for convenience in carrying them to and from the laboratory. It was not necessary to place the lids on the bottom of the cylinders as the latter rested firmly and evenly on the bottom of the case.

If there is any delay before the insects are separated from the samples, it may be desirable to place each cylinder in a suitable canvas bag in order to prevent the escape of small insects due to any irregularity in the fit of the lids.

The separation of the insects from the sample is carried out as follows: A large vessel, enamelled white on the inside and containing clean water, is required. We used a vessel 18 ins. high and 18 ins. in diameter. The same volume of water was used for each sample and the surface of the water was well below the top of the vessel.

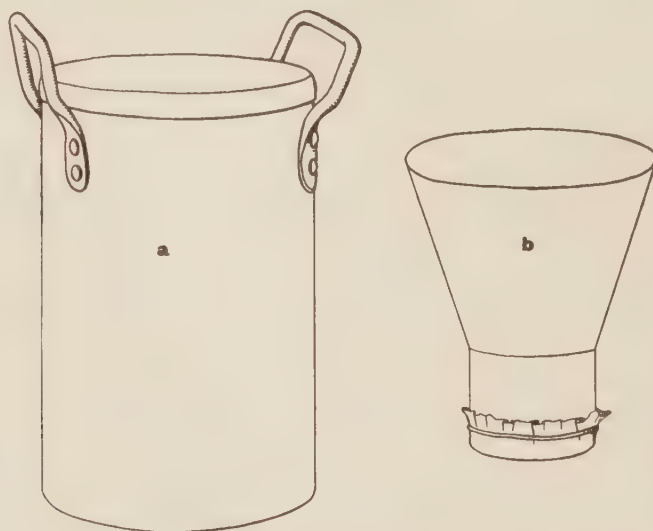


Fig. 1. *a*, cylinder for sample of pasture and soil; *b*, apparatus for removing insects from water.

The cylinder containing the sample is slowly submerged in the water, the bottom lid being removed. The sample is allowed to drop to the bottom of the vessel and the cylinder is removed. The insects float up to the surface of the water and are skimmed off with a bell-mouthed cylinder, one end of which is closed with a piece of fine muslin (fig. 1, *b*). The insects are placed in 70 per cent. alcohol, and counted at leisure.

The pasture sample may be slightly agitated with a stout wire in order to release any insects entangled in the herbage. This must be done carefully otherwise an undue amount of debris floats up to the surface of the water.

The following figures are given as examples of the number of individuals of *Smynturus viridis* (total of three samples in each case) which were obtained by the method:—

29.4.32	...	...	...	926
20.5.32	...	...	...	2,413
21.6.32	...	...	...	210

OBSERVATIONS ON THE LIFE-HISTORIES, NUTRITIONAL REQUIREMENTS AND FECUNDITY OF BLOWFLIES.

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Introduction.

The observations recorded here have been made during the last two years, while breeding stocks of blowflies for the study of experimental strike in sheep. The work has been carried out in the Council's laboratory and insectaries at Canberra. Canberra is situated at an altitude of 1,900 feet, on the western slopes of the southern highlands of New South Wales, in $35^{\circ} 15' \text{ S. Lat.}$, $149^{\circ} 15' \text{ E. Long.}$ It possesses a temperate climate, the mean summer temperature being 67.5°F. , and the mean winter temperature 41.8°F. The average rainfall is 22 inches, most of which falls in the winter.

During the summer months the flies have been bred in cages and in cubicles in the blowfly insectary. The cages measure 18 by 16 by 16 inches and consist of a wooden floor, two glass sides and a gauze side and roof. The cubicles form part of the blowfly insectary; each measures 9 by 6 feet and is 7 feet high. They have concrete floors and the walls and ceilings are composed of phosphor-bronze gauze, 60 meshes to the inch, the diameter of the wire being 0.004 inches. This gauze has excellent light-transmitting qualities. All the cubicles are covered by the common high glass roof of the insectary. Temperature, humidity and infiltration of sunlight within the insectary are quite similar to those prevailing outside, although the intensity of the sunlight is somewhat reduced.

During the winter months, April to October inclusive, smaller stocks of flies have been maintained in cages in the warm room. This room is a concrete cellar and is warmed by an electric radiator mounted in front of a fan. The temperature is kept at $20\text{--}22^{\circ}\text{C.}$ by means of a thermoregulator, and light and also heat are supplied during the day time by a 1,000 watt lamp. Sunlight cannot enter this room and ventilation is poor. These conditions are in sharp contrast with those obtaining in the insectary, where there is abundant sunlight and ventilation. Nevertheless, flies live well in both situations and breed as freely in the one as in the other. The food of the flies has been fresh liver, dates and cane-sugar. A plentiful supply of water was maintained at all times in jars with cheesecloth wicks.

For breeding maggots in bulk, galvanised-iron maggot-proof trays were used. When dealing with small numbers of maggots they were placed on liver on sand in cylindrical glass jars about 6 inches high and $3\frac{1}{2}$ inches in diameter. These are provided with screw-top lids, the tops of which are punched out and a circle of gauze soldered in. These make excellent breeding jars, but, when dealing with *Lucilia*, it was found necessary to stand each jar in a maggot-proof tray, as the fully-fed maggots are very active and can escape from under a screw-top lid. Bullock's liver was used almost exclusively in rearing maggots.

Five species of blowflies have been studied: *Lucilia sericata*, Meig., *Lucilia cuprina*, Wied., *Chrysomya rufifacies*, Macq., *Calliphora stygia*, Fabr. and *Calliphora augur*, Fabr. Of these the two species of *Lucilia* survive well and breed readily in captivity, and for this reason and because they are the most serious sheep flies (*L. cuprina* in Australia and *L. sericata* in other parts of the world) more observations have been made on them than on the other species. A few observations were also made on the tertiary fly, *Peronia rostrata*, R.D.

Descriptions and figures of these flies, which all cause strike in sheep, may be found in the Report of the Joint Blowfly Committee (1933). Their larvae have also been described in detail recently (Fuller, 1932).

Breeding Habits.

All these flies live normally in carrion. During the spring they multiply rapidly, and a definite seasonal prevalence has been observed (M. E. Fuller, unpublished). *C. stygia* becomes most abundant in early spring; *C. augur*, *L. cuprina* and *L. sericata*, a little later. *Ch. rufifacies* is most abundant in early summer. All species decline in abundance during January—usually a hot dry month—and increase again for a short period in autumn, diminishing rapidly as winter approaches. In winter only *C. stygia* is present in the field, other species hibernating as pupae or prepupae.

The period required for complete development from egg to adult varies greatly with the temperature and with the species. The following times have been noted under summer conditions in the insectary:—

<i>L. sericata</i>	}	...	...	...	14–21 days, average 17 days.
<i>L. cuprina</i>					
<i>Ch. rufifacies</i>	...	...	...	12–18	„ „ 15
<i>C. augur</i>	...	...	...	21–22	„
<i>C. stygia</i>	...	...	...	25–26	„
<i>P. rostrata</i>	...	...	...	29–31	„

The periods are longer in spring and autumn, and in winter *C. stygia* has been observed to spend over two months in the larval and pupal stages. During summer in general the egg period occupies 12–24 hours, the maggots feed for 3 to 6 days, and then pass into a prepupal stage which lasts on the average 2–4 days. In this stage they take no food and become very active, seeking a suitable place to pupate. *Lucilia* prepupae exhibit a particularly intense activity and possess remarkable powers of squeezing through narrow places. The pupal period follows, and it is here that the most constant variation in the different species occurs. It is shortest in *Ch. rufifacies* (average 5 days); a little longer in *Lucilia* (average 8 days); considerably longer with *C. augur* (average 13 days); and longest with *C. stygia* (average 14 days).

The two species of *Lucilia* hibernate as prepupae. Usually towards the end of March some maggots from each batch of eggs will hibernate and some will pupate and emerge after a gradually lengthening pupal period. Emergences have been observed as late as June, the flies then only surviving for a few days. As a rule during April less and less maggots pupate, until finally practically all remain as prepupae until September, when they begin to pupate and some emerge. The majority, however, do not emerge until October. *L. sericata* appears about a fortnight earlier than *L. cuprina*. In Europe also *L. sericata* hibernates as a prepupa (Davies, 1929), (Holdaway & Evans, 1930), but at Grootfontein in South Africa, Smit (1931) found that *L. sericata* hibernated partly as prepupae and partly as pupae. Adults also could be found in the field during the winter. In Brisbane, Queensland, *L. sericata* breeds all the year round, but a prolongation of the prepupal period up to 3 weeks has been noted in winter (Johnston & Tiesg, 1922).

From some observations on *L. sericata* it appears that it is very difficult to check the hibernating process, once it is initiated. Thus, half the maggots of a batch reared in the warm room was placed in the insectary for 24 hours, the minimum temperature during this period being 0°C. They were then returned to the warm room, but did not pupate for eight weeks although the remainder of the batch, not subjected to cold, pupated after two days and emerged nine days later. For

a week some of the hibernating prepupae were alternated from warm to cold conditions daily, some being subjected to a temperature range of 20–7°C., and others to a range of 35–7°C. These fluctuations in temperature, however, did not stimulate pupation.

It is probable that *C. augur* and *Ch. rufifacies* pass the winter as pupae, but exact experimental evidence is lacking. Development of late batches of eggs proceeded slowly, and flies emerged in early winter and died without ovipositing. In Iowa, Roberts (1930) states that *Cochliomyia macellaria*, Fabr.—the screw-worm fly of America—disappears in winter and the district is repopulated each spring from the south.

In captivity in the warm room all species can be maintained throughout the winter at a constant temperature of 20°C., the egg to adult period occupying approximately the same time as in midsummer in the insectary. The following periods were observed :—

<i>L. cuprina</i> }	...	...	...	14–16 days
<i>L. sericata</i> }	...	...	...
<i>Ch. rufifacies</i>	...	...	...	12–14 "
<i>C. augur</i>	...	...	...	18–20 "
<i>C. stygia</i>	...	...	...	20–24 "

The period can be shortened by increasing the temperature, at any rate up to 30°C. At that temperature *Ch. rufifacies* has been bred through in 9 days and *L. cuprina* in 11 days. Cousin (1929 f) states that 33°C. is the optimum temperature for *L. sericata* maggots. The egg-period varies greatly with the temperature. Eggs of *L. cuprina* will hatch in 19–20 hours at 20°C., and in 45–48 hours at room temperature in mid-winter (July).

The periods given here closely correspond with those recorded by Johnston & Ties (1922). They were working in Brisbane (27° 28' S. Lat., 153° 2' E. Long), and therefore development was rather more rapid than in Canberra. The minimum egg to adult periods observed were 12 days for *Lucilia sericata** and 9 days for *Ch. rufifacies*. Johnston & Hardy (1923), also working in Brisbane, give similar figures for the majority of the larvae observed, but found very great variation in the prepupal period, especially of *Lucilia* sp. They do not, however, state whether those individuals the prepupal period of which was unduly prolonged were as large and well-fed as those which pupated rapidly. It has sometimes happened that a few individuals of a batch would persist as prepupae after the remainder had completed their development. These, however, were usually stunted larvae, which had failed to grow as rapidly as the majority although food was equally accessible to all. Disturbance also delays pupation. In one controlled experiment, removing the prepupae from the sand and weighing them daily was found to prolong the prepupal period for four days. This condition of inertia may be similar to the "diapause" described by Cousin (1929, e, f, g, h and i).

Emergence usually begins in the morning, and of a given batch the first flies to emerge are almost all males. On the following day males and females appear and finally females preponderate. The development of colour in the green species may take an hour or longer, the fly being at first greyish brown, then purple and finally green. This colour change occurs equally well in total darkness and in sunlight.

Development of the Reproductive Organs.

In the two species of *Lucilia* the development of the reproductive organs in the adult fly differs in the sexes. In the female it is dependent upon an adequate diet,

* It is possible that their material was a mixture of *L. sericata* and *L. cuprina*.

whereas in the male development is independent of diet. It is probable that the same is true for other species of blowflies. In the male a few active sperms may be found by dissection of the testes within 12 hours of emergence, and the proportion of active sperms increases during the next two days, although the flies have fed only on water or sugar and water. Johnston & Tiegs (1922) noted that male blowflies are sexually mature soon after emergence, and Cowan (1932) has made similar observations on *Phormia regina*.

In one experiment a number of females were isolated on emergence and fed on sugar, fresh liver and water (an adequate diet). On the second day males, which had been fed only on sugar and water, were added to the cage containing the females, after removal of the liver. No protein was added to the diet until the seventh day, when a piece of fresh liver was placed in the cage. Fertile eggs were deposited on it at once.

Female flies, on the other hand, do not become sexually mature until they have fed once on adequate protein material. Fresh liver or muscle supplies the necessary protein but sheep dung is inadequate. Flies (*L. cuprina* and *L. sericata*) kept on a diet of cane-sugar, dates and fresh flowers, with or without the addition of fresh sheep-dung, showed no development of the ovaries. When fresh liver was added to the diet, an immediate and rapid growth of the ovaries was observed on dissection and ova were deposited 2-3 days later. This development occurred if liver was not given until the tenth day, fertile eggs being laid on the thirteenth day. Salt (1932) and Cousin (1929, a) made similar observations on *L. sericata*. Cousin, however, obtained no eggs if protein was withheld for 10 days. Roubaud (1922) and Glaser (1923) have stressed the importance of a mixed diet for the housefly, *Musca domestica*. Blowflies also thrive best on a mixed diet. Both species of *Lucilia* will produce fertile eggs on a diet of fresh liver and water. When, however, an easily assimilable carbohydrate, e.g. cane-sugar, is added to the diet, the ovaries mature more rapidly and the flies live longer than on liver alone. A preoviposition period of 7-10 days was observed on a diet of liver and of 5-6 days on a mixed diet.

Development of the ovaries is also dependent on temperature, varying from 5 days in midsummer to 3 weeks in late autumn. Smit (1928) in South Africa has recorded varying preoviposition periods, the minimum being 5 days in January and the maximum 29 days in August. In the warm room the preoviposition period usually lasts 5 to 7 days, the minimum observed being 4 days.

Ch. rufifacies becomes sexually mature in 6 days in summer and 9-10 days in early autumn in the insectary. The shortest preoviposition period observed in the warm room was 7 days.

C. stygia takes from 10-14 days to become sexually mature in captivity. It will frequently lay soft, infertile eggs for several days before normal eggs are produced.

C. augur also takes from 10-14 days to become sexually mature in captivity. Although it normally deposits living larvae, it will also lay soft, infertile eggs for some days before normal larviposition occurs. In one experiment with this species the flies began to lay immature eggs on the 11th day but it was not until the 20th day that normal larvae were deposited.

P. rostrata was observed in one experiment to lay fertile eggs 5 days after emergence.

The reproductive organs of both sexes of *Calliphora erythrocephala*, Meig., have been described by Lowne (1890-1892), and other species appear to conform closely to this type. *C. augur*, however, in accordance with its larviparous habit, possesses a modification of the utero-vaginal canal. That section of the canal posterior to the openings of the spermathecae and parovaria and internal to the ovipositor is usually short and narrow. In *C. augur* it becomes greatly expanded laterally and

is supplied with a rich network of tracheae. It is here that the eggs lodge after fertilisation and while development of the maggots takes place. As soon as they are deposited, the maggots are able to break through the chorion and begin feeding.

Oviposition stimuli.—The females usually deposit their eggs on carrion, but will also lay them on living sheep. In captivity both species of *Lucilia* oviposit freely on fresh liver but will also do so on putrid liver. *L. sericata* has been observed to lay eggs on liver in which other maggots (*Chrysomyia*) had developed and left some days previously. Both species of *Lucilia* will also oviposit on clean raw wool if it is first moistened (M. R. Frenay, unpublished). They will also oviposit on dates when carrion is not available. Roberts (1930) observed *L. sericata* to lay eggs on banana skin.

Copulation appears to provide some essential stimulus for oviposition. In one experiment about 40 female *L. cuprina* were isolated on emergence, fed on an adequate diet and offered fresh liver regularly. Although, on dissection, it was found that the ovaries were well-developed, they did not lay eggs for a period of five weeks. Then a few young males were introduced into the cage. Copulation occurred at once, and fertile eggs were deposited on the following day. Smit (1931) stated that females, isolated from males, lived 42–65 days without laying eggs. Cousin (1929c), however, stated that oviposition in *L. sericata* is independent of fertilisation and that infertile females laid eggs at irregular intervals in the same way as fertile females. Cowan (1932) has commented on the importance of the stimulus supplied by the male. Glaser (1923) working with *M. domestica* found that unfertilised females laid fewer eggs than fertile ones and concluded that the male provided an important stimulus.

Ch. rufifacies will oviposit on either fresh or putrid liver and on soiled wool. It prefers dark places for oviposition and in the warm room oviposits almost exclusively at night, when the light is turned off. In the cubicles, it shows a tendency to go downwards, ovipositing freely at times on the gauze at the bottom of the drain pipe, where conditions are moist and dark but not suitable for larval development, there being no available food except a few dead flies. This tendency to work downwards for oviposition is also shown by its decided preference for liver at the bottom of a jar rather than in a flat petri dish. This species has been observed to oviposit freely on dates, even in the presence of liver. It has also oviposited on raisins and banana skin.

C. stygia will oviposit on fresh liver, and *C. augur* has been observed to deposit larvae on both fresh and putrid liver. These species have not been observed to oviposit on purely carbohydrate food. When *C. augur* is confined in small glass tubes, it will frequently deposit its larvae on the glass. This may be due to some extent to active movements on the part of the maggots when the fly becomes exhausted, for when a female dies, the maggots will frequently escape and begin to feed on the maternal tissues.

The oviposition reflex, then, is not strictly associated with a suitable larval environment. It is evidently more in the nature of a reaction to a tactile stimulus. Cousin (1929d) has commented on this in regard to *L. sericata*. Gravid female flies visit carrion to feed as well as lay eggs. They feed first and then oviposit. The mature ovaries themselves cause considerable abdominal distension, and this is increased by taking food—whether it be protein or carbohydrate. Under these conditions the ovipositor is extended and if it comes in contact with a substance supplying some particular stimulus, oviposition may begin, whether that substance be a suitable larval food or not.

Fecundity and Longevity.

A male and female *L. sericata* were placed together in a cage immediately on emergence. The cage was kept in the insectary from 27th February to 8th April

and in the warm room from 8th April to 15th May 1931. The usual food was given, *i.e.*, dates, cane-sugar and water, and fresh liver was supplied every second day. The female laid the first batch of eggs on the 6th day, continuing to lay eggs at gradually increasing intervals of time until her 67th day when the thirteenth and last batch was laid. Both flies died on the 77th day. A control cage containing about 50 flies was set up at the same time and subjected to the same conditions. The first oviposition occurred on the 7th day, and the last on the 63rd day. The last fly died on the 76th day. The following table gives the progeny of the isolated pair.

TABLE I.
Progeny of one Pair of Lucilia sericata.

No. of oviposition	Age of fly in days	Progeny					Remarks
		Dead pupae	Adult males	Adult females	Total adult flies	Adults + dead pupae	
1	6	21	37	34	71	92	Many maggots escaped from jar
2	9	0	78	100	178	178	
3	11	102	37	38	75	177	Many parasitised by <i>Mormonella</i>
4	13	14	102	111	213	227	
5	16	0	95	123	218	218	
6	18	0	93	79	172	172	
7	23	0	79	107	186	186	
8	26	15	84	100	184	199	
9	29	0	95	118	213	213	
10	32	0	95	98	193	193	
11	37	0	103	90	193	193	
12	54	0	77	98	175	175	
13	67	2	78	70	148	150	
		154	1,053	1,166	2,219	2,373	

The average oviposition was therefore 182 eggs, or, omitting the first, the figures for which are incomplete, 190 eggs. The proportion of sexes in the adult progeny was 47.5 per cent. males and 52.5 per cent. females.

A similarly controlled experiment was not made with *L. cuprina*, but one female was observed to lay on an average 186 eggs every second or third day during the first three weeks of life. It is probable that the fecundity and longevity of this species is similar to *L. sericata*, but that considerable individual variations exist in both species.

The most long-lived and prolific fly studied was a hybrid. In this experiment a pair of hybrids—the progeny of a male *L. cuprina* and a female *L. sericata*—was placed together in a cage and kept exclusively in the warm room. Both these flies were indistinguishable from a typical *L. cuprina*. The male lived only 12 days,

but the female lived 94 days and produced fourteen batches of eggs. The 13th batch was only partially fertile and of the 14th batch only five eggs hatched. The sperms which are normally stored in the spermathecae had apparently been exhausted. Sperms, therefore, survived within the female for at least 51 days and probably for about 7 days longer. Cowan (1932) noted that in *Phormia regina* the spermatozoa survived in the female for at least 11 days after the death of the male. The following table gives the progeny of this pair of hybrids:—

TABLE II.
Progeny of one Pair of Hybrid Lucilia.

No. of oviposition	Age of fly in days	Progeny						
		Unhatched eggs	Preserved maggots	Dead pupae	Adult males	Adult females	Total adult flies	Grand total
1	7	—	8	0	128	113	241	249
2	11	—	7	17	108	102	210	234
3	12	—	6	7	112	109	221	234
4	14	—	7	11	111	98	209	227
5	16	—	6	5	111	100	211	222
6	18	—	6	15	112	115	227	248
7	21	—	0	0	105	138	243	243
8	26	—	0	1	104	130	234	235
9	30	—	0	0	118	123	241	241
10	33	—	0	0	104	123	227	227
11	36	—	0	0	111	125	236	236
12	43	—	0	49	93	76	169	218
13	51	100	0	0	29	26	55	155
14	63	197	5	0	0	0	0	202
		297	45	105	1,346	1,378	2,724	3,171

The average oviposition was 226 and the proportion of sexes in the adult progeny was 49·4 per cent. males and 50·6 per cent. females. The first 12 batches were not examined for unhatched eggs as hatching appeared to be complete.

Salt (1932) has recorded the number of eggs produced by isolated females of *L. sericata* and gives 1,883 as the maximum obtained. He obtained fertile eggs from a fly 66 days old and sterile eggs from one 91 days old. Presumably in this case also the stock of spermatozoa had been exhausted. The maximum life recorded by the same observer was 104 days for a female and 68 for a male. Smit (1928) recorded 91 days as the maximum obtained by him and (1931) he gives 1,094 as an average total oviposition per female. He was dealing with *L. sericata*. The total egg production of the hybrid fly reported above was over 3,000, which far exceeds any records in the literature available to me. This prolific egg production may possibly be due to "hybrid fertility."

Detailed experiments have not been carried out with the other species of blowflies but a few observations have been made on individual ovipositions and by dissection of mature insects.

<i>Ch. rufifacies</i> (bred flies)	average oviposition	187
<i>C. stygia</i> (captured flies)	" "	264
<i>C. stygia</i> (bred flies)	" "	157
<i>C. augur</i> (captured flies)	" larviposition	50

The maximum number of eggs laid in one batch by an isolated, captured *C. stygia* was 313.

The average figures given above agree fairly closely with those obtained by Froggatt & Froggatt (1916). The authors dissected captured flies and gave the following averages :—

<i>Calliphora villosa</i> (= <i>C. stygia</i>)	250–275 eggs
<i>Calliphora oceaniae</i> (= <i>C. augur</i>)	40–50 "
<i>Calliphora rufifacies</i> (<i>Ch. rufifacies</i>)	about 200 "
<i>Lucilia sericata</i>	" 200 "

In *Lucilia* the number of ova a fly can produce at each oviposition seems to be definitely related to the size of the fly and is thus directly dependent on the amount of food obtained during the larval stage. In one experiment small mature flies having an average weight (immediately after death) of 11.4 mgm. were dissected and the number of mature ova counted. The average was 83 per female. Large mature flies weighing 42.0 mgm. contained on an average 175 ova, which is near the average obtained by ovipositions (182 for *L. sericata* and 186 for *L. cuprina*).

Female flies usually live longer than males. The average life in captivity is about seven weeks for *Lucilia*, rather less for *Chrysomya rufifacies* and considerably less for both species of *Calliphora*. It is frequently found that over 50 per cent. of the *Calliphora* population will die in the first two weeks after emergence, *i.e.* before they reach sexual maturity. This makes it difficult to breed these flies in bulk in the way *Lucilia* may be bred.

Inbreeding does not seem to have any injurious effect upon the flies. The *L. sericata* stock started from a known single oviposition has been maintained for two years without the addition of any fresh blood and shows no signs of deterioration. The *L. cuprina* stock, started from what was apparently a single oviposition has been maintained for one year and appears equally vigorous. *Ch. rufifacies* has been inbred through many generations without impairment of vigour. *C. stygia* has been inbred for at least four generations, without adding new stock, but, owing to its relatively short life in captivity, it has been customary to utilise captured flies for many experiments. This also holds for *C. augur*.

Two mutations have appeared in the *Lucilia* stocks, a white-eyed mutant of *L. cuprina* and a short-winged mutant of *L. sericata*. The white-eye character behaves as a Mendelian recessive. These mutants will be described in another paper.

Sex-Ratio.

The sex-ratio of both species of *Lucilia* has been found to be very nearly 1 : 1. By adding together the figures obtained in a number of experiments, where the sex of the bred flies was recorded, and including both species of *Lucilia*, the following figures were obtained : 8,235 males, 8,350 females ; *i.e.* 49.7 per cent. males and 50.3 per cent. females, or a ratio of 0.98 males : 1.0 females. In a small series of experiments on *L. cuprina*, starvation in the larval period did not have a marked effect on the sex-ratio, the proportion in 345 flies being 50.7 per cent. males and

49.3 per cent. females. This is in marked contrast to the work of Herms (1928) on *L. sericata*. He found a definite relationship between the larval feeding period and the sex-ratio of the resulting flies. The proportion of males increased considerably as the feeding period was shortened. Smit (1931) found that starvation had no effect on the sex-ratio but his figures are very small.

Summary.

L. sericata, *L. cuprina*, *Ch. rufifacies*, *C. stygia* and *C. augur* have been bred through many generations in captivity. These flies were bred in artificial light as well as in sunlight. Inbreeding had no effect upon activity, fecundity or length of life.

A diet of protein is necessary for the maturation of ova but not of spermatozoa.

Oviposition is not strictly associated with a suitable larval environment, but is more in the nature of a response to a tactile stimulus. Copulation appears to provide an essential stimulus for oviposition.

No evidence of parthenogenesis has been obtained and unfertilised females did not lay eggs.

The maximum oviposition observed was 3,171 ova by a hybrid *Lucilia*. This fly lived 94 days.

A total oviposition of 2,373 ova was observed in a *L. sericata*. Both parent flies lived 77 days.

The number of ova a fly can produce at one time is dependent on its size and thus on the amount of food obtained in the larval stage.

The sex-ratio for *Lucilia* is very close to 1 : 1. Starvation in the larval period did not have a marked effect on the sex-ratio.

It is possible to cross the two closely related species of *Lucilia*, and the *cuprina* characters appear to be dominant. It is unlikely that this cross occurs in the field.

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OBSERVATIONS ON *AËDES AEGYPTI*, L. (DIPT. CULIC.) UNDER CONTROLLED ATMOSPHERIC CONDITIONS.

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Methods of Breeding.

The adults of *Aëdes (Stegomyia) aegypti*, L., the yellow-fever mosquito, which were used in these experiments were bred from a stock which had been kept for several years in the laboratory by the method described by Leeson (1931). This method was used for breeding, with the following modifications designed to ensure a continuous supply of adults, so that the daily removal of a large number would not deplete the stock to a serious extent. It was found that from 80 to 200 adults could be obtained daily, the only attention necessary, apart from the care of the guineapig used for feeding the females, being the replenishment of water, the feeding of larvae and the collection of pupae, which occupied ten minutes every third day.

The larvae were kept in enamelled metal dishes, 6 inches in diameter and 3 inches deep, floating in an iron tank, the temperature of which was electrically controlled and maintained at 25–30°C. The use of dishes which could be removed facilitated the collection of pupae. The mosquito cage which contained the tank was roofed and partly surrounded with thick cellophane and brown paper, so that the air, warmed and moistened by the water in the tank, did not escape. The temperature of this air was about 27°C. and the relative humidity between 80 and 90 per cent., as shown by observing the dew-point. Food for the larvae was derived from brown bread crumbs (Macgregor, 1929) sprinkled on the water once in three days. If too much was supplied, a scum appeared at the surface of the water and the larvae died; if too little, pupation ceased. Previous experiments showed that dead beech leaves or certain unicellular green algae were unsatisfactory. When the former were used, the pupae were large but few and the larvae often lived for several weeks before pupation. When bread was used, the usual time occupied in development from egg to pupa was six days.

The pupae were collected and placed in a separate container for emergence. Very few adults failed to emerge, and several did so from pupae stranded on the sides of wet glass tubes.

The adults in the warm moist air above the water laid eggs readily, but fed on the guineapig only when it was partly shaved. Eggs were laid on the surface of the water, but they soon sank owing to the movement of the feeding brushes of the larvae. As soon as all these were removed, hundreds of eggs were seen floating on the surface for several days.

Manipulation.

For the rapid transference of adults the following simple method was used. The instrument into which air was sucked, shown in fig. 1, consisted of a glass chamber, 1 inch long and 0·8 of an inch in diameter, which could be connected with the mouth by a piece of rubber tubing. The other end tapered and, by means of a short length of rubber tubing, joined a glass tube 0·3 of an inch in diameter.

This was twice bent at right angles for removing adults from inside bottles and its tip was not dilated, so that it could be inserted through holes in stoppers. Also the high speed of the air at this point facilitated catching. The adults were prevented by mosquito netting from passing completely through the apparatus. This method of transference was found very useful, because hundreds of adults could be collected and ejected without injury in a few minutes merely by sucking or blowing air through the mouth-piece.

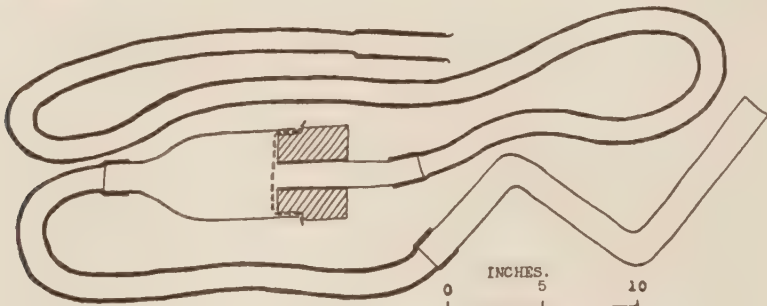


Fig. 1. Instrument for transferring adult mosquitos.

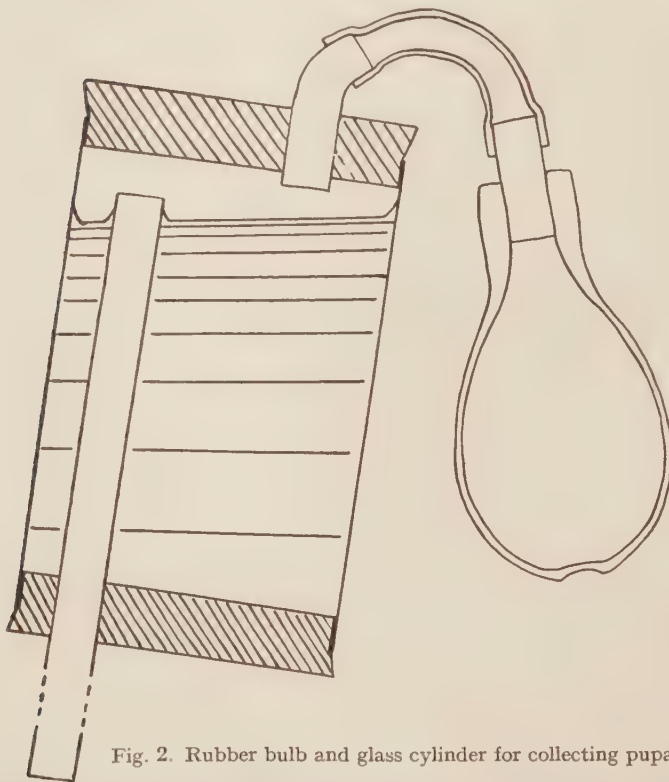


Fig. 2. Rubber bulb and glass cylinder for collecting pupae.

For collecting pupae the device shown in fig. 2 was used. Water was sucked by means of a large rubber bulb into a wide glass tube in the manner shown. In this way a large number of pupae could be taken from one container before being emptied into another.

Length of Life.

Adults of both sexes having been kept over water from 1 to 5 hours after emergence, were placed singly in clean glass tubes covered with gauze. These were

TABLE I.

*Results of Experiments on Length of Life of Aedes aegypti.**

	Temperature, °C.	Relative humidity, %	Saturation deficiency, mm. Hg.	Males unfed				Females unfed			
				Number of individuals	Mean survival in days	Max. survival in days	Standard deviation	Number of individuals	Mean survival in days	Max. survival in days	Standard deviation
Unfed ...	10	100	0.0	20	14.4	29.5	8.6	20	16.7	30.5	7.1
	23	0	21.0	27	1.4	2.5	0.3	22	1.5	2.5	0.2
	23	30	14.7	20	2.5	3.5	0.6	20	2.5	3.5	0.5
	23	50	10.5	20	3.6	5.5	1.1	20	3.0	3.5	0.5
	23	70	6.3	20	4.3	5.5	0.9	20	3.9	5.5	0.9
	23	80	4.2	20	5.1	8.5	1.4	16	4.7	6.5	0.9
	23	90	2.1	20	5.1	10.5	1.6	20	4.6	6.5	0.9
	23	100	0.0	40	7.8	15.5	2.4	40	7.0	12.5	2.2
	30	30	22.2	20	1.4	2.5	0.5	20	1.4	2.5	0.5
	30	100	0.0	20	6.7	10.5	2.1	20	6.4	10.5	1.6
Females fed on 4th day	23	0	21.0					2	2.5	2.5	0.0
	23	30	14.7					13	3.9	5.5	1.4
	23	80	4.2					10	8.0	11.5	2.8
Females fed on 5th day	23	80	4.2					5	6.9	9.5	3.3
Females fed on 6th day	23	60	8.4					7	6.5	8.5	2.6
	23	80	4.2					2	9.0	9.5	0.5
Females fed on 7th day	23	0	21.0					20	2.7	4.5	0.9
	23	30	14.7					8	3.3	3.5	0.7
	23	100	0.0					20	10.0	12.5	1.9
Total ...	...	...	...	Males : 227	Females :			305			

* The times for fed females indicate the periods subsequent to feeding.

then kept in desiccators at constant temperatures in air of definite relative humidities controlled by sulphuric acid. The insects were kept in darkness and showed very little activity. They were examined once every 24 hours. In this way the length of life, correct to 24 hours, was observed, the recorded figure being the number of days till death minus 12 hours. Death was recorded when no movement could be induced. Other females, after having been fed on blood, were treated in the same way as the starved ones. Only those were used in which the abdomen was fully distended with blood, so that the conditions were as uniform as possible. Altogether 532 individuals were used under 11 sets of atmospheric conditions.

The results are summarised in Table I, and it will be seen from the standard deviations and the numbers employed that the differences between means in most experiments are significant; in some of the experiments with mosquitos which had fed, the differences are not significant.

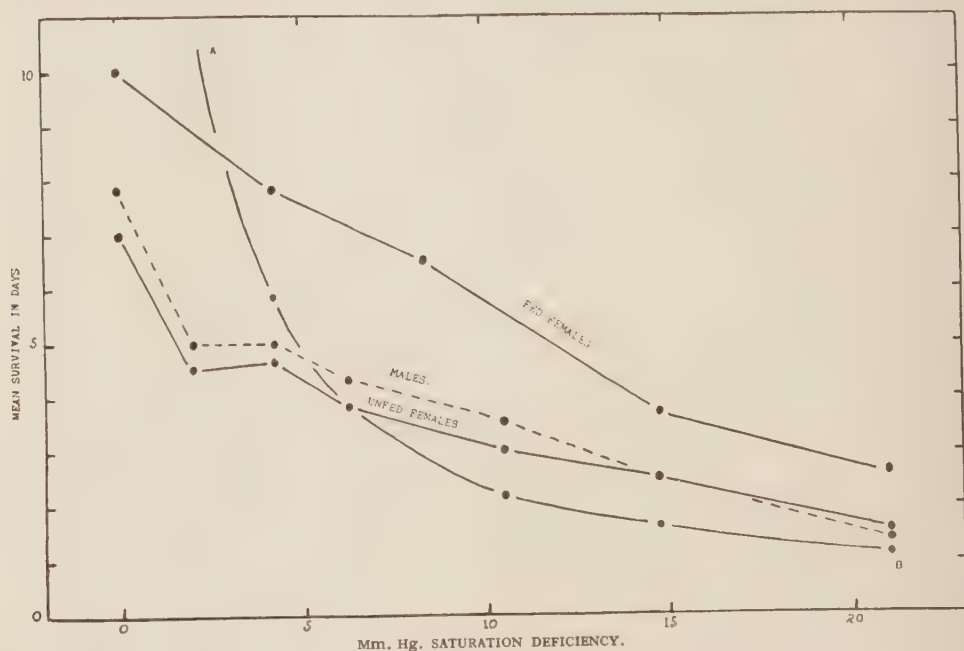


Fig. 3. Survival of fed and unfed mosquitos at 23°C., and different humidities, with curve (A-B) through expected survival point.

Temperature.—In the insects exposed to saturated air, it is seen that the mean survival periods at 10°, 23° and 30°C. are, for the females, 16.7, 7.0 and 6.4 days respectively. The difference of 7°C. (23–30°C.) has only a very slight effect when compared with the difference of 9.7 days between 10°C. and 23°C. Possibly this is partly explained by the fact that at 10°C. the insects become dormant after a few days. Touch will then stimulate them to move only when they are warmed. They remain in this condition for as long as 10 days, whereas those at the higher temperature can always be induced to fly until a few hours before death.

At 23°C. and 30°C. in dry air, when the saturation deficiency was about 21 mm. with the temperature difference as great as 7°C., the male survival periods were identical and those of the females nearly so.

Humidity.—This has a comparatively important effect on length of life at these temperatures. The points for fed females in fig. 3 show the survivals of groups of females fed on the 4th–7th days and subsequently exposed to the experimental

conditions. They are shown separately in Table I, but as the duration of life prior to feeding seems to make no difference to the subsequent survival, all are united in the graph.

Is the length of life proportional to saturation deficiency? This question is answered by taking the observed duration of life at a moderate relative humidity (70 per cent.) and plotting the expected values at other humidities (fig. 3). This gives the curve AB, while it will be observed (if the values for saturated air are not considered, since life is then terminated by other causes) that the lines through the actual survival points approximate to straight lines. This discrepancy is seen from whichever value the theoretical points are calculated.

Taking only experiments at 23°C., length of life in fed and unfed mosquitos is evidently partly determined by loss of water by evaporation; but clearly the simple conditions under which this is proportional to saturation deficiency are modified. This species, even after feeding, appears to have no very efficient mechanism for retarding loss of water by evaporation.

Sex.—At 23°C. and saturation deficiencies below 14.7 mm., survival of the males was consistently longer than that of the females. The significance of this difference at its greatest value (at 100 per cent. relative humidity) may be tested in the following way: The difference is 0.8 days (7.8–7.0); the formula for its standard error (S.E.) is $\sqrt{(\text{S.E. of } \sigma\sigma)^2 + (\text{S.E. of } \phi\phi)^2}$, which is 0.54. As this is more than half the difference, the difference is not statistically significant. This does not prove that no difference between male and female survival periods exists; it merely states that on my set of figures the difference may be real or may be due to insufficiency of figures.

Food.—Whether the females were starved for 4 or 7 days before feeding, the subsequent lengths of life depend principally on temperature and humidity. It is seen that the effect of feeding is simply to prolong the life, the period after feeding being greater than the survival of unfed insects but having a similar relation to saturation deficiency.

Feeding.

Field observations on many species of mosquitos, for instance *Anopheles maculipennis*, Mg. (Necheles, 1927) and *Aedes* spp. (Rudolfs, 1925) might suggest that atmospheric humidity, in addition to temperature, has an important effect on activity. To examine this question experimentally an apparatus was designed to allow female mosquitos to feed on the human arm under variable conditions of controlled atmospheric temperature and humidity. A current of air of known absolute humidity was obtained by blowing air through two Woulfe's bottles in a water-bath. These contained pumice and either sulphuric acid or water. By varying the temperature of the latter, control of the vapour pressure of the air was readily effected, this being regulated to give the required saturation deficiency at the temperature of the feeding chamber. Glass wool in U tubes removed spray which would have been carried through and evaporated at a higher temperature, thus raising the absolute humidity. The air then passed into the feeding chamber submerged in a second water-bath, both baths being kept at a constant temperature by hot water circulating in copper tubing. As shown in fig. 4, the feeding chamber consisted of a glass cylinder with a thick rubber bung at each end. The lower one carried a thermometer and two glass tubes for introducing and removing air, the latter one being covered with gauze to prevent mosquitos being carried through. The upper bung, which rested on the edge of the cylinder and was hermetically sealed to it by elastic bands, could be instantly removed to uncover a circular area, 2.2 sq. inches, of green leno on which the fore-arm was placed. A speed of air of 2.8 cc. per second was found necessary to counteract the effect of heat and moisture given off by the skin.

After passing through the whole apparatus, the air entered a dew-point hygrometer, where it could be tested at any stage of the experiment. This instrument had to be heated when the dew-point used was high, *e.g.* 30°C.

Finally, all conducting tubes not under water in the container were enclosed in tubes of running hot water, which enabled the whole conducting system to be

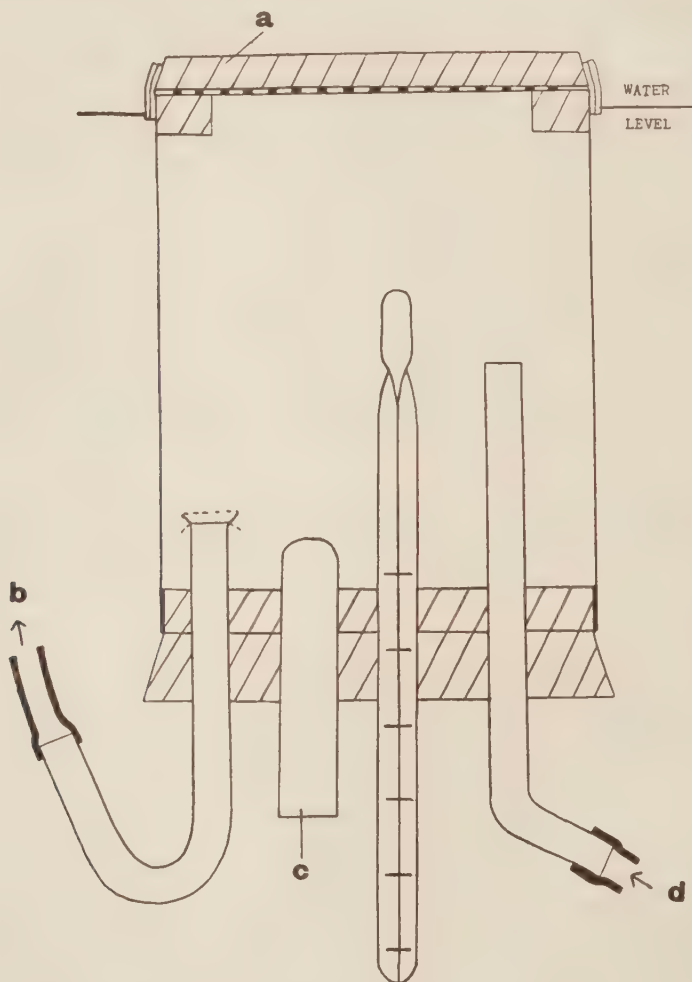


Fig. 4. Part of apparatus for experiments on biting; the feeding chamber: *a*, rubber lid covering net; *b*, air to hygrometer; *c*, stopper closing hole for introduction of mosquitos; *d*, air of controlled humidity.

dried in a few seconds after washing, and also prevented condensation. This was particularly necessary when the air was saturated at 30°C., as a single drop of condensed water would spoil an experiment.

This "saturation" method of obtaining all but the lowest humidities had the advantage over the use, for instance, of sulphuric acid solutions, that it has unlimited variation, and no renewal of solution is necessary.

After a number of preliminary experiments with different ages, lengths of exposure, etc., the conditions were ascertained at which a reasonably large number of females (one-third) would bite at 25°C. in nearly saturated air in the apparatus, and then results at other conditions could be compared. Females between 6 and 7 days old were used and, after being removed from damp air in the dark 23°C. incubator, were left in the apparatus for 10 minutes before the arm was applied for 5 minutes. A longer preliminary exposure was found unnecessary, while with a shorter one fewer fed. Six was chosen as the maximum number of mosquitos for any one experiment, as this was the largest number which fed during preliminary observations. The accuracy of dew-point readings was ensured by rapidly sucking dry air past the silver thimble of the hygrometer. Thus the slightest trace of dew was seen, the gradual condensation and evaporation of which would have been impossible to detect.

TABLE II.

Summary of Results of Experiments on Feeding.

Temperature °C.	Relative humidity %	Saturation deficiency mm. Hg.	Number used	Number which bit	Percentage which bit
25	94	1.5	43	14	33
25	0	23.7	34	2	6
25	60	9.5	33	4	12
30	95	1.5	38	15	39
30	0	31.7	36	4	11
30	70	9.5	35	6	17
20	91	1.5	37	2	5
35	96	1.5	36	5	11
35	77	9.5	36	6	17
15	88	1.5	27	0	0
40	83	9.5	24	0	0
			379		

A summary of the results is shown in Table II and fig. 5. The conditions of the experiments are probably comparable to those under which a mosquito flies in search of its food, because often the females would immediately feed when applied to the skin in a small glass tube, although in the experimental tube they would not do so in 5 minutes. In other words, feeding in this experiment depends on the process of flying in search of food rather than the distinct reactions which occur when the female touches the skin. The same thing applies to mosquitos in the cage.

Temperature.—The numbers biting in damp air at a saturation deficiency of 1.5 mm. show that, of the temperatures used, activity was by far the greatest at 25°C. and 30°C. Considering the results at these two temperatures, it is seen that at the saturation deficiencies of 1.5 and 9.5 mm. more mosquitos bit at the higher temperature in each case. Moreover, at 30°C. and a saturation deficiency even of

31.7 mm. (R.H. 0 per cent.), more bit than at 25°C. and a lower saturation deficiency. The low points at 35°C. and 40°C. are not due to any reluctance to feed owing to excessive activity, since at these temperatures activity was visibly low. At 15°C., 35°C. and 40°C., activity was much reduced and hardly any mosquitos flew. Also at 10°C. in the experiments on length of life, it was noticed that they did not fly and walked very slowly.

Humidity.—It is evident that at 25°C. and 30°C., at which temperatures most biting occurred, either high humidity had a definite effect in inducing larger numbers to bite or else low humidity prevented biting.

These results are in accordance with those of previous work on *Aedes aegypti*. Thus Marchoux, Salimbeni & Simond (1903) found that the females would feed mainly between 26°C and 35°C. Between 19°C. and 25°C. they are slow to suck blood and below 15°C. they do not do so at all (Howard, Dyar & Knab, 1912; Connor, 1922).

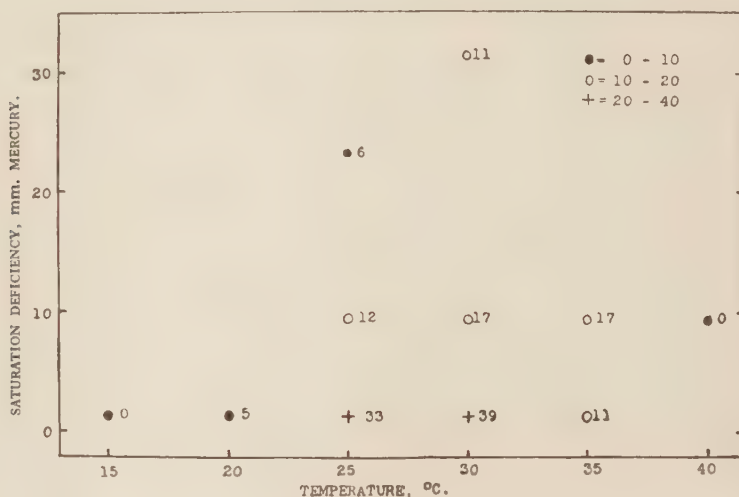


Fig. 5. Percentages of females which bite under different conditions of temperature and humidity.

The experiments support field observations in showing the importance of humidity in connection with feeding. Necheles suggests that *Anopheles maculipennis* bites when a fall in temperature produces a rise of relative humidity. The present results with *Aedes aegypti* indicate that biting occurs most frequently at high humidities at the optimum temperature of activity.

Owing to the effect of atmospheric humidity on the length of life of fed and starved *Aedes aegypti*, it might be expected that on a long flight in search of food they would be affected by loss of water by evaporation. It is not surprising, therefore, that the females should seek blood principally in damp air.

Similar conclusions with regard to *Culex fatigans*, Wied., were reached by Mayne (1930), when considering the question whether the females could "be induced to bite in an atmosphere of relative humidity in which they are unable to survive desiccation following a blood meal." He found that at temperatures of 91.5–95.5°F. (33–36°C.) biting did not occur below a relative humidity of 52 per cent.

I have much pleasure in thanking Dr. P. A. Buxton for suggesting this work and for reading and criticising the manuscript.

Conclusions.

These observations show that this species belongs to the class of insects which do not possess an efficient mechanism for retarding loss of water, and which do not require one because their mode of life is such that they can readily take in water (Buxton, 1932) either by drinking it, as noted below, or by sucking blood or fluid from plants in both sexes (Gordon, 1921 ; other species, Lewis, 1932). Many females kept in jars of water prolonged life beyond 7 days—the survival period of starved adults in saturated air—by drinking water, often fully distending the abdomen.

The feeding experiments, in showing that the females bite mainly at high humidities at the temperatures of maximum activity, indicate that the behaviour of this insect is specially adapted to avoid undue loss of water. Otherwise exposures to high saturation deficiencies might have particularly unfavourable effects as, unlike many species of mosquitos, *Aedes aegypti* is a day biter.

Summary.

Methods of breeding and manipulating *Aedes aegypti* are described. Experiments on length of life were carried out with 534 mosquitos under eleven sets of conditions of atmospheric temperature and humidity. Also, 379 females were given an opportunity to suck blood under 11 sets of conditions. The following conclusions were reached :—

1. The length of life of starved mosquitos at 23°C. is very much dependent on humidity, but it cannot be directly related to saturation deficiency.
2. In these experiments there is no significant difference between the mean survivals of males and females, the former being generally longer.
3. The survival periods of fed and unfed females have a similar relation to humidity, the fed ones surviving the conditions for a longer period, irrespective of the date of feeding.
4. The effect of a change of temperature of 7°C. on the survival at 23°C. and 30°C. is much less than would be expected when the long survival period at 10°C. is considered.
5. In the absence of any efficient physiological adaptation for retarding loss of water, the females, possibly for this reason, seek a blood meal mainly in saturated air at the temperature of maximum activity.

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THE BIONOMICS OF *OTIORRHYNCHUS CRIBRICOLLIS*, GYLL.

By H. G. ANDREWARTHA, M.Agr.Sc.

Historical.

This weevil was described by Gyllenhall⁶ from specimens collected in Southern France. Grandi⁴ states that it is to be found throughout the Mediterranean region of Europe, and the same author⁵ records it as doing considerable damage to lucerne (*Medicago sativa*) in Portici. Delassus² records it as attacking olives in Algeria. The first record of the insect in Australia was made by Koebele⁷ who described it as attacking olives around Adelaide in 1890. Quinn¹⁰ described it as an enemy of the orange around Adelaide. Since then it has been recorded by Lea⁸ as attacking a very large number of plants. It has been known in Western Australia for over thirty years.

Material and Methods. *

Most of this work was done during 1930 in the Department of Agriculture of Western Australia, but some confirmatory observations were made on specimens reared in the insectary of the School of Agriculture in the University of Melbourne during 1931.

Both adults and larvae were collected in the field from time to time, and some larvae were reared from eggs laid in the insectary. In order to observe the oviposition adult weevils were confined in cages made by replacing the bottoms of tobacco tins with wire gauze. The tins were placed over brown paper which was stretched over moist soil. As they were laid, the eggs fell through the gauze wire on to the paper from which they could be removed and counted with a minimum of trouble.

The eggs were incubated in glass incubation cells similar to those described by Searle.¹¹ These were made by cutting glass tubing of $\frac{1}{2}$ inch diameter into lengths 1 inch long and closing one end with a layer of plaster of Paris $\frac{1}{4}$ inch thick. These cells were embedded in a dish of moist soil. The eggs were thus constantly in contact with a moist surface. At first they were placed directly on the plaster, but this method had to be abandoned as the larvae invariably burrowed straight into the plaster on emerging. It was found that this difficulty could be completely overcome by interposing a piece of strong smooth brown paper between the eggs and the plaster.

Incubation Period of the Eggs.

When first laid the eggs are a clear white. From 3 to 6 days after they are placed under the moist incubation conditions, a colour change occurs. They pass through a series of intermediate greys, ultimately becoming a dark lustrous brown.

About 5 per cent. of the eggs incubated did not pass through this colour change, but died and rotted while still white. Of a total of 686 eggs incubated, 346 or 51.6 per cent. produced larvae, 35 or 5.2 per cent. failed to change colour, and 305 or

* This work was carried out with the assistance of a grant of £120 (for apparatus and travelling) from the Science and Industry Endowment Fund. I desire to register my very sincere gratitude to the Trustees for their assistance. I am also anxious to express my thanks to the Government Entomologist of Western Australia, Mr. L. J. Newman, F.R.E.S., who was ever ready, throughout the course of the investigation, to give me the benefit of his very wide experience of entomological problems in that State.

43.2 per cent. passed through the normal colour change but failed to hatch. In the case of a number of these death was due to their being damaged in handling, as they are very fragile and easily injured when first they are laid.

Details of the incubation period have been given in Table I, along with the mean maximum and mean minimum temperatures as recorded in the insectary, during the experiment. These results were obtained from 11 incubation cages.

It is apparent that the shortest period was 14 days; the maximum emergence occurred between the 20th and 28th days; the longest period taken was 37 days. The average incubation period was 22.3 days.

TABLE I.

Incubation cage	Date commenced	No. of larvae	Period of Incubation (days)			Av. daily max. °F.	Av. daily min. °F.
			Min.	Max.	Mean		
A	23.4.30	17	18	23	20.9	72.7	57.1
B	23.4.30	16	18	27	21.3	72.8	57.3
C	23.4.30	41	21	27	22.6	72.8	57.3
D	12.5.30	30	15	23	17.5	72.1	57.4
E	13.5.30	34	14	28	19.1	70.9	57.0
F	14.5.30	17	22	27	22.4	70.5	56.7
G	19.5.30	9	18	28	22.5	68.8	55.8
H	22.5.30	37	19	29	24.2	66.6	55.3
I	30.5.30	44	21	37	23.5	68.0	55.5
J	3.6.30	63	22	34	25.4	67.0	55.3
K	5.6.30	38	22	32	26.0	66.9	55.3
Total	—	346	—	—	—	—	—
Average	—	—	18.5	28.6	22.3	—	—

Although no attempt was made to determine just what humidity is required to produce development in the eggs, it was nevertheless clearly demonstrated that they would not hatch under conditions as dry as those obtaining in the orchard prior to the beginning of the winter rains.

A reference to the pages dealing with oviposition shows that in the insectary some eggs were being laid as late as the middle of June. Remembering this, and allowing for differences which may occur between field and laboratory conditions, one might estimate that in the field the time during which the larvae are hatching extends from 14 days after the first winter rains until the end of July.

The Larval Period.

The external morphology of the larva has been so completely described by Grandi⁹ and Lockwood & Kieffer⁵ that I do not propose to add anything to their descriptions.

Habits.—The larvae emerge after the early winter rains which also germinate the seeds of the cover crop which grows in the orchard throughout the winter. It

is on the fine fibrous roots of these plants that the larvae feed, only casually attacking the fine roots of the apples, and never, within the limits of my observations, attacking the large roots of the trees as described by Lea⁸. The plants grown as a cover crop include a wide range of annuals, amongst which are *Cryptostemma calendulaceum*, *Medicago denticulata*, *Plantago* spp. and many trefoils. The larvae seem to show very little discrimination and were observed to feed upon the roots of all the plants mentioned.

Throughout the winter the larvae feed at distances varying from 3 to 12 inches below the surface. Most of them descend to a depth of about 12 inches to pupate.

TABLE II.

Instar	No. of larvae	Head width in mm.			
		Observed			Calculated
		Min.	Max.	Mean	
1st	10	0.35	0.37	0.36	—
2nd	15	0.41	0.43	0.42	0.42
3rd	10	0.48	0.51	0.49	0.49
4th	7	0.58	0.60	0.57	0.58
5th	6	0.65	0.70	0.68	0.68
6th	4	0.77	0.81	0.78	0.80
7th	7	0.88	0.94	0.90	0.94
8th	9	1.08	1.17	1.09	1.10
9th	10	1.22	1.33	1.27	1.30
10th	49	1.43	1.62	1.53	1.52

Dyar's Law.—In studying insects whose larval life is spent in the soil, it is extremely difficult to determine either the number or the duration of the larval instars. This difficulty would largely disappear if it could be demonstrated that Dyar's Law³ provides an accurate criterion for determining the instar of an individual which had not been measured in a previous instar.* In other words, it is necessary to demonstrate that the law applies just as accurately to the average head-width of an instar as it does to the head-width of an individual. Direct evidence of this is practically unobtainable for a form which, like *Otiorrhynchus*, spends its larval life below the surface of the soil. But I believe that I have accumulated sufficient circumstantial evidence to show that in *Otiorrhynchus cribricollis* Dyar's Law can be applied as a sufficiently accurate criterion for determining the instar of an individual which has not previously been measured.† My evidence falls into four categories:—

(1) The head-widths of 147 larvae were measured accurately. These measurements were then arranged in ascending order of magnitude. It was found that they could be divided naturally into 10 groups. These groups were not always very

* See footnote on page 379.

† In this connection it is interesting to mention that Taylor¹³ has evolved a statistical method for calculating the duration of the instars of leaf-mining and other inaccessible larvae. He assumes that Dyar's Law can be used in the way mentioned above; but he does not attempt to provide evidence to substantiate his assumption.

clearly defined. Sometimes the difference between the largest measurement of one group and the smallest of the group immediately above it was less than the difference between the largest and smallest of one and the same group. But in the latter case there was always a series of intermediate measurements, whereas in the former there was not. Further, the average head-widths of the groups formed a sufficiently accurate geometric progression. Also the average measurement in any group tallied sufficiently closely with the expected width when calculated by Dyar's Law. It was therefore decided that the figures that are given in Table II provide sufficient evidence for the conclusion that there are 10 instars in the larval life of *Otiorrhynchus cribricollis*.

The geometric mean used to obtain the last column in Table II was the mean of the ratios of increase at each ecdysis. The ratios for each ecdysis are given in Table III. Each figure in column 2 is obtained by dividing the average head-width of an instar by the average width of the instar preceding it. Thus the ratio for the first ecdysis is 1.172 obtained by dividing 0.42, the average for the second, by 0.36, the average for the first.

TABLE III.

Ecdysis	Ratio
1st	1.172
2nd	1.174
3rd	1.162
4th	1.181
5th	1.161
6th	1.153
7th	1.205
8th	1.163
9th	1.207
Mean	1.175

(2) There is a very marked difference in the structure of the spiracles during different instars. This difference lies mainly in the relative sizes of air-tubes and atrium; but in addition the air-tubes of the first instar are provided with annuli, whereas those of the second and subsequent instars are not. Fig. 2 indicates the changes that occur in the different instars; the differences between A and B are too marked to leave any doubt that at least one ecdysis has occurred between the instar from which A was drawn and that from which B was drawn. That only one ecdysis has supervened is proved by the fact that I have been able to obtain an exuvium from a larva whose spiracle is figured in fig. 2, B, while the exuvium itself contained the spiracle drawn in fig. 2, A. The head measurements of all the larvae whose spiracles correspond to fig. 2, A fall within the limits designated as first instar in Table II, and all those whose spiracles correspond to fig. 2, B have head measurements within the group called second instar. This is complete proof that the application which was made of Dyar's Law in Table II is valid for at least the first two instars.

The evidence provided by the spiracles in the succeeding instars is not so conclusive. Many of them were measured, and although there is a successive increase in the size of the spiracle for each instar, along with a decrease in the relative length

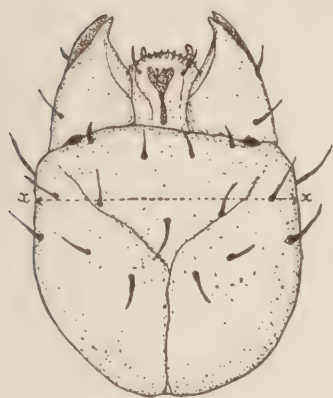


Fig. 1. Head of 2nd instar larvae, $\times 50$.
 $x-x$, head-width for Table II.

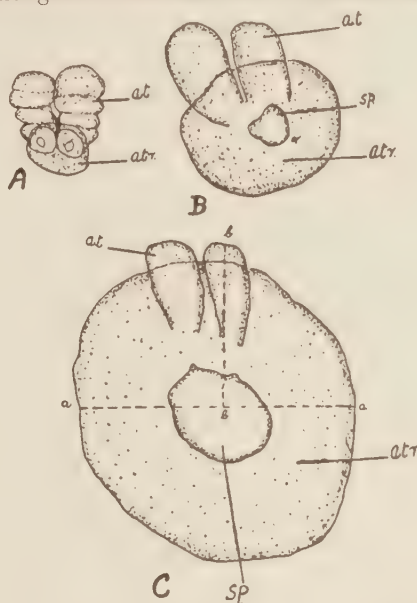


Fig. 2. Surface view of prothoracic spiracles: A, 1st instar, $\times 500$; B, 2nd instar, $\times 300$; C, 10th instar, $\times 300$; *at*, air-tubes; *atr*, atrium; *sp*, spiracular opening; *a-a*, diameter of atrium; *b-b*, air-tube length for Table IV.

TABLE IV.

Instar	No. measured	Diameter of Atrium			Air-tube length	Spiracle ratio
		Min. μ	Max. μ	Mean μ		
1st	4	10	10	10	16	0.6
2nd	9	21	24	23	22	1.0
3rd	2	28	28	28	22	1.3
4th	3	31	35	33	24	1.4
5th	3	37	40	39	26	1.5
6th	3	42	44	43	27	1.6
7th	1	—	—	51	32	1.6
8th	6	56	62	58	35	1.7
9th	2	66	74	70	42	1.6
10th	3	80	86	82	42	1.9

These measurements are all from larvae which had been cleared in potash and mounted, or else mounted direct from life, in De Faure's fluid.

of the air-tube with respect to the atrium, these changes are not sufficiently definite to provide such conclusive evidence of the validity of any of the other ecdyses as for the first. These measurements are given in Table IV. I consider that the increases in size of the spiracles are sufficiently sudden to establish the validity of the first, sixth, seventh, eighth and ninth ecdyses. In the table the minimum, maximum and mean diameters of the atrium are given, as well as the ratio obtained by dividing the mean diameter of the atrium by the mean length of air-tube ($\frac{a}{b}$ in fig. 2).

(3) The mandibles of a larva at the beginning of an instar are always sharply bidentate (fig. 3, A). At the end of an instar they are more or less worn, as the result of the abrading effect of the soil particles which coat the root on which they feed. This worn condition is particularly noticeable in the later instars, which last longer and during which more feeding occurs (fig. 3, B). I have found mandibles which were so sharply bidentate as to indicate that the larva was near the beginning of an instar in larvae whose head-widths would place them in the first, second, fifth, sixth, eighth, ninth and tenth instars respectively. Also I have found larvae with mandibles worn, indicating that they were approaching the end of an instar, whose head-widths corresponded to the first, fourth, fifth, sixth, seventh, eighth, ninth and tenth instars respectively.

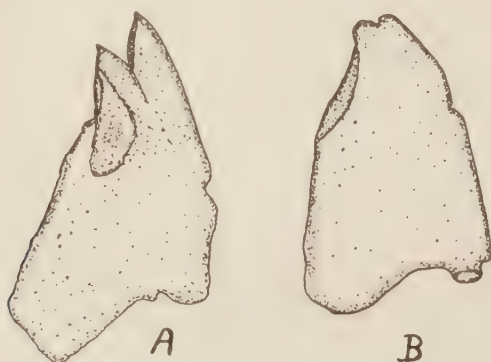


Fig. 3. A, mandible of 10th instar larva at the beginning of an instar; B, mandible of 9th instar larva nearing the close of the instar.

This evidence suggests that the application of Dyar's Law has correctly placed the first, fourth, fifth, seventh, eighth and ninth instars.

(4) When a larva is ready to shed its skin, the old cuticle splits just behind the head. The head-capsule then ruptures ventrally and slips off. The cuticle then shrivels, and as it contracts, it carries the old head-capsule backwards with it. Eventually the whole exuvium slips off the posterior end of the larva. I have found a number of larvae to which the exuvium was still attached. In every case the head-widths of the larva and its exuvium corresponded to successive instars as defined by Table II. The ecdyses that have actually been demonstrated thus are the first, fourth and seventh.

It is now evident that the method used in Table II for determining the number of larval instars is supported by at least one of the three criteria brought forward to test it for all the ecdyses except the second and third.

It is very probable that further searching would result in the gaps in this evidence being closed. As it is, I consider that there is ample evidence included under

paragraphs (2), (3), and (4) to show that Dyar's Law* holds good when it is applied to the average head-width of an instar. It follows that we now have a reliable method for determining the number of instars in the life of soil-inhabiting, leaf-mining and other inaccessible larvae. Also it is demonstrated that Taylor's¹³ statistical method for determining the duration of the instars of such larvae rests on a sound basis in so far as his use of Dyar's Law is concerned.

Duration of Larval Instars.—I did not have sufficient material to determine the duration of the larval instars, but Table V throws a little light on this matter. The samples dealt with were all collected from the same orchard.

It appears that by the first week in August 90 per cent. of the larvae have passed their seventh instar, and more than 75 per cent. have passed the eighth. By the middle of September 76 per cent. were already in the final instar and 86 per cent. had passed the eighth. The first pupae were observed on 23rd October and by the first week in November pupation was in full swing. Assuming that the majority of the larvae were emerging about the end of May (the winter rains commenced early in May in the district concerned) it would seem that the first seven instars occupied only about 2 months with an average of about 9 days in each. As 76 per cent. of the larvae had reached the tenth instar by 13.ix.30, apparently the eighth and ninth instars occupied together about 4 weeks. The final instar apparently lasts for about 6–10 weeks.

TABLE V.

Date	Percentage of larvae in specified instar							Total
	4th	5th	6th	7th	8th	9th	10th	
7.viii.30	—	—	—	3.1	21.7	43.4	31.8	32
13.ix.30	1.1	1.7	4.9	2.5	3.7	10.1	76.0	346
8.x.30	—	—	—	—	5.8	16.5	77.7	34
23.x.30	—	0.4	—	0.8	1.5	19.1	77.1	266
24.xi.30	—	—	5.0	—	20.0	5.0	70.0	20
19.xii.30	—	—	—	—	50.0	50.0	—	4

These figures are only very approximate, but they serve to indicate that the earlier instars are of comparatively short duration and that the last is the longest.

Aestivation.—A reference to Table V shows that in the sample taken on 13.ix.30, 10 per cent. of the larvae had not passed the 7th instar, and these are too small to pupate with the others. As there is no food for them during the summer, during which time the orchards are kept under clean fallow, they are unable to continue their development. They follow the moisture down into the subsoil (I have found them as deep as 3 feet below the surface) where they form an earthen cell and aestivate throughout the summer. When the winter rains start in the following year, they commence feeding again, gradually working their way to the surface, and pupate in the following spring.

These aestivating larvae occur consistently wherever the adults are to be found. The explanation of their occurrence is not clear. They may arise from eggs which

* Dyar³ showed in 1890 that the head-widths of an individual Lepidopterous larva in its successive instars follows a geometric progression. This law has since been applied to other orders, viz., Coleoptera, Hymenoptera (Symphyta) and even Collembola. But so far as I am aware, it has not previously been applied to the average head-widths of successive instars.

are laid very late in the season. They may be larvae which hatch at the normal time but have difficulty in obtaining a sufficient supply of food. Or they might be larvae which, even though they hatch at the normal time and have the normal supply of food, yet develop abnormally slowly owing to some physiological difference in their constitution.

That lack of food can delay development for a considerable time without causing death is suggested by the following small experiment. Fifteen newly emerged larvae were placed in each of two pots containing clover on 26.iv.31. All the plants were removed from one pot on 30.vi.31. Both were examined on 29.viii.31. Table VI shows the result.

TABLE VI.

	No. of larvae in specified instar					
	3rd	4th	5th	6th	7th	8th
Pot A plants removed ...	5	2	—	—	—	—
Pot B control ...	—	—	—	1	5	2

Pupation.

Pupation takes place about 12 inches below the surface in an earthen cell which has previously been formed by the larva. The incidence of pupation in the field was studied by collecting samples from time to time. The results are shown in Table VII. The figures are for samples taken from the soil, and thus after 13.xi.30 they do not give a true picture, as they fail to take into account the individuals which had emerged as adults.

TABLE VII.

Incidence of Pupation in the Field.

Date	Larvae		Pupae		Adults	
	No.	%	No.	%	No.	%
8.x.30 ...	232	100.0	—	—	—	—
22.x.30 ...	440	97.7	10	2.3	—	—
13.xi.30 ...	45	30.0	105	70.0	—	—
4.xii.30 ...	4	50.0	1	12.5	3	37.5

A number of mature larvae were collected in the field and put away in plaster of Paris cells which were kept moist by capillarity, so that the process of pupation might be watched.

At first the wing-pads and legs are very small. They increase in size but remain gummed down to the body. A few days before the pupal stage ends a colour change sets in. The eyes are the first organs to become pigmented, becoming quite dark before any of the other parts show any colour. The mandibles colour next, followed by the apices of the leg segments, the disk of the thorax and the venter of the abdomen. Finally the elytra darken and the pupal stage ends.

The Adult.*

The first adults emerge from the soil and commence feeding about the third week in November. The last ones emerge about 10th December. The period of maximum emergence occurs about the first week in December.

Weevils were collected in the field on 15.iii.30. Seventy of these were placed, 10 in each of 7 cages, in the insectary in order to obtain data upon the length of their life as adults. The number of deaths occurring were recorded daily. The experiment lasted from 15.iii.30 to 12.vii.30. The greatest number of deaths occurred between 20.iv.30 and 17.v.30. During this period 66 per cent. of the weevils died. A further 19.7 per cent. died at other times during the experiment. The remaining 14.3 per cent. hibernated. The period during which the greatest number of deaths were occurring was from the middle of April to the middle of May. Thus the normal life of an adult weevil is about 5 months or 150 days.

Hibernation.—About 14 per cent. of the adult weevils hibernate. Under the mild conditions of the Western Australian winter this can hardly be termed a true hibernation, but merely consists of living through the winter in a comparatively inactive condition. They feed a little at comparatively long intervals on the bark of the dormant apple trees.

In order to observe their habits and the duration of their life 70 weevils which had over-wintered in the field were placed, 10 in each of 7 cages, in the insectary, fed daily, and daily records of their deaths taken. The experiment was initiated on 6.x.30, and lasted until 9.ii.31 when it had to be abandoned. No deaths occurred until the seventh week. Deaths then occurred spasmodically during the next seven weeks, but none occurred in the last five weeks during which the experiment was operative. Altogether 18 weevils representing 25.7 per cent. of the total died. Thus 75 per cent. of the weevils which over-winter actually reach the second autumn or egg-laying period. Since 14 per cent. of the original generation hibernated it follows that this 75 per cent. represents 11 per cent. of the original generation. In other words, 11 per cent. of each generation of adults live for 17 months instead of the normal 5 months.

Feeding Habits.—The most striking feature about the feeding period of the adult *Otiorrhynchus* is that it is divided into two periods by a long quiescent spell during which the weevil does not feed at all. This feature is evident both from observations taken in the field and by experiments conducted in the insectary. In the field feeding commences about the last week in November and lasts until the end of December. The second period of feeding commences about the middle of February and lasts into the late autumn. During the six weeks between these two periods of feeding the weevils can be found beneath the soil at the butts of the trees, but they do not ascend them at night to feed.

In the insectary 70 weevils which commenced feeding on 27.xi.29 ceased on 5.i.30. They recommenced on 20th February and fed into the late autumn. It was noticed that the feeding was not regular. On some nights much more food was consumed than on others. It was also noticed that the weevil laid most of their eggs on nights on which they were not feeding.

That the quiescent spell which occurs between the two periods of feeding is the outcome of some physiological condition within the weevil, and not a direct reaction to the heat and dryness of the conditions prevailing throughout the summer, is suggested by a small experiment that was conducted. Twenty weevils were starved between 20.xii.30 and 3.i.31, and then fed. They were kept under conditions exactly comparable (except for lack of food) to the conditions of those which ceased feeding on 5.i.30, but they continued to feed until 20.i.30.

*Details of the habits of this stage, the nature of the injury, and a discussion of possible control measures are not treated here as they have been dealt with in a previous paper¹.

Food-plants.—The adult weevils have been observed feeding in the field on the following plants :—

- Rosaceae—Apple, pear, peach, plum, quince,
blackberry, rose and cherry.
- Fagaceae—*Quercus suber*.
- Solanaceae—*Solanum nigrum*.
- Plantagineae—*Plantago lanceolata*.
- Chenopodiaceae—*Chenopodium album*.
- Compositae—*Hypochoeris radicata*.

In addition the weevils fed freely on the following plants when given access to them in the insectary :—

- Leguminosae—*Phaseolus vulgaris*, *Medicago sativa*.
- Polygonaceae—*Rumex* sp.
- Cruciferae—*Brassica campestris*.
- Compositae—*Helianthus* sp.
- Bignoniaceae—*Tecoma* sp.
- Rubiaceae—*Coprosma* sp.
- Convolvulaceae—*Ipomoea purpurea*.

It is obvious from this list, which includes 21 different plants and 12 families, that the weevils are very polyphagous and can therefore be regarded as potential pests of any of the cultivated plants which remain green throughout the summer.

Oviposition.—The weevils for this experiment were collected on 15.iii.30. They were placed 10 in each of 7 cages and fed daily. The eggs laid were recorded daily. The first eggs were laid on 18.iii.30. The laying followed a tri-modal curve. The first climax was reached during the fortnight between 18th and 29th March, when 1,033 eggs were laid ; in the next 7 days only 41 eggs were produced ; but in the following week 1,698 were laid. The numbers then dwindled rapidly, until during the fortnight between 26.iv.30 and 10.v.30 no eggs were laid.

The following week saw the final and smallest climax, when 220 eggs were produced. The numbers then dwindled gradually until in the week between 8.vi.30 and 14.vi.30 the last 3 eggs were laid. The period of maximum egg production in this experiment was from the 5th to 26th April, during which time 2,033 out of a total of 3,550 eggs were laid. The maximum number of eggs laid in any one cage (containing 10 weevils) was 639 and the minimum 378. The average number to a weevil was 50.6.

Although the bulk of the eggs are laid in the autumn, a few are laid by the hibernating weevils in the spring. These weevils start feeding regularly about the last week in September and commence egg-laying 4 or 5 weeks later. In order to discover how many eggs were laid at this season, 70 of these weevils were placed in egg-laying cages on 6.x.30. The first eggs were laid on 28.x.30 and the last on 22.xii.30, but 135 out of a total of 139 were laid between 27.x.30 and 17.xi.30. Not all the weevils laid eggs ; the 10 in cage 4 produced none. The others ranged between 4 and 52, with an average of 2.

From these experiments it follows that the total number of eggs laid by any one weevil must be computed from those laid at the two periods. During the autumn period the average number was 50.6. During the spring period 14 per cent. of the same generation averaged 2.0 each. This would be equivalent to 0.28 eggs to a weevil for the whole generation. Hence in this experiment the average number of eggs laid by each weevil was $50.6 + 0.28 = 50.88$.

As each weevil died it was dissected and the developed eggs remaining in the ovaries were counted. Many contained none ; some contained only a few ; but one contained as many as 24. The total number was 221. Had these all been laid,

they would have brought the total for each weevil up to 54. It is reasonable to suppose that the unnatural conditions of the experiment were responsible for some at least of the premature deaths, and that in the field the average number of eggs laid is something over 51 and probably lies between 55 and 60.

Efforts were made to determine where and how the eggs were laid in the field. Sheets of brown paper were placed on the soil under trees on which weevil damage was severe, but on no occasion were any eggs found on the sheets. Apparently the eggs are not dropped from the food-plant to the ground as Grandi⁵ states.* All attempts to observe the actual act of oviposition were failures, chiefly because the weevils are nocturnal in their habits and become inactive the moment that light is focussed on them.

Circumstantial evidence suggests that the eggs are laid on or under the surface of the soil when the weevils are wandering from one tree to another. This evidence can be summarised as follows: (1) It has been demonstrated that the weevils wander freely from one tree to another; (2) the larvae are found fairly evenly distributed through the orchard and are not more numerous under the trees than between the rows; (3) the larvae do not have any great tendency to wander after hatching from the egg, but can always be observed to burrow straight into the soil; (4) the eggs are mostly laid by weevils which are not feeding on the night of the egg laying.

Parthenogenesis.—It was first demonstrated by Grandi^{4,5} that *Otiorrhynchus cribricollis* reproduces normally by parthenogenetic eggs. He examined specimens from all over the Mediterranean basin of Europe without discovering a single male. Similarly, I have dissected many hundreds collected at various times of the year, and from various districts, without once finding a male. Parthenogenesis is known to occur in other species of the genus *Otiorrhynchus*, viz. *O. turca* (Silantiev¹²) and *O. ligustici* (Vassiliev¹⁴). Although parthenogenesis has not been definitely demonstrated for *Otiorrhynchus sulcatus* it is very likely that the phenomenon occurs in that species too (Smith^{11a}). It is a pest in various countries, including New Zealand and certain parts of the United States. Most of the references to it include the statement that males are very rare.

The value of the phenomenon to the insect lies in the advantage it gives it in its spread into new territory. It means that a single individual, be it egg, larva, or adult, is capable of establishing a colony in a new locality. This faculty, of course, increases the potentialities of the weevil as a pest to cultivated crops.

Summary.

(1) The history of *Otiorrhynchus cribricollis* in Australia is traced and records of its distribution in other countries are cited.

(2) Methods used in the experiments are described.

(3) The incubation period of the egg was found to vary between 14 and 37 days. The average was 22.3 days.

(4) The habits of the larva are described. Dyar's Law was applied to determine the number of instars, which was found to be 10.

(5) The normal duration of larval life is from May to October or a period of about 5 months.

(6) About 10 per cent. of the larvae aestivate through one summer. These have a larval life of about 17 months.

* Dr. Grandi has since informed me that he has not witnessed the actual oviposition in the field owing to the difficulties introduced by the nocturnal habits of the insect. His statement that the eggs are allowed to fall to the ground from the plants during feeding operations was deduced from his observations of the habits of the weevil.

(7) Normal life of the adult is from November to April, about 5 months, but some (about 11 per cent.) hibernate through one winter and thus live 17 months.

(8) The adults feed in two seasonal periods separated by an interval of about 6 weeks, during which time they are inactive.

(9) The adults have been observed to feed upon 21 different plants, representing 12 different families.

(10) Most of the eggs are laid in the autumn, but a few are laid in the spring.

(11) The average number of eggs laid by a weevil under experimental conditions was 50.8.

(12) The eggs are probably laid on or under the surface of the soil.

(13) The weevils normally reproduce parthenogenetically. No male has been discovered in many hundreds of specimens dissected.

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COMPARATIVE OBSERVATIONS ON THE MORPHOLOGY AND BIOLOGY OF SOME HYMENOPTEROUS PARASITES OF CARRION-INFESTING DIPTERA.

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1. Introduction.

The following observations constitute part of a study on the Hymenopterous parasites of certain carrion-infesting Diptera. These were made at Toulouse, France, in the course of a wider investigation which was in progress for the Commonwealth Council for Scientific and Industrial Research on the biological agencies which play a part in regulating the abundance of the sheep blowfly, *Lucilia sericata*, Meigen. The observations here recorded, though mainly of academic interest, have served as an aid in the more practical aspects of the investigation.

2. The Species studied.

The species studied were *Aphaereta minuta*, Nees, a parasite of first and second instar larvae, *Alysia manducator*, Panzer, which attacks third instar larvae, and *Mormoniella vitripennis*, Walker (*Nasonia brevicornis*, Ashmead), a puparial parasite. A few observations were also recorded on *Aspilota nervosa*, Haliday, a parasite of

half-grown larvae of *Aphiochaeta* sp. (PHORIDAE), and are included here for comparative purposes. *Aphaereta minuta*, *Alysia manducator* and *Aspilota nervosa* belong to the subfamily ALYSIINAE of the BRACONIDAE, *Mormoniella vitripennis* to the PTEROMALIDAE. Three of the species studied, namely, *Aphaereta minuta*, *Alysia manducator*, and *Mormoniella vitripennis* have been encountered during field studies; the fourth, *Aspilota nervosa*, was found under insectary conditions parasitising its host in carrion-remains after the completion of other breeding work.

Little has been recorded previously on the biology of the genus *Aphaereta* except for a few notes published by Graham-Smith¹⁰ on *A. cephalotes*, Hal. The same author¹⁰ has also recorded the emergence of *Aspilota nervosa* from the puparia of *Diranchis* sp. A great deal of work has been done on *Alysia manducator* by Graham-Smith⁹, Altson¹, Myers¹⁵, and Morgan¹⁴, but the anatomy of the larval stages has not yet been described in any detail. *Mormoniella vitripennis* is another species already well studied, but some observations have been made on it, in order that a more complete sequence of parasites attacking the pre-imaginal stages of the hosts may be included in the comparative study.

3. Hosts.

The hosts from which *Aphaereta minuta* has been bred in this study are *Lucilia sericata*, *Calliphora erythrocephala* and *C. vomitoria*. *Alysia manducator* was also bred from the above species and in addition from *Lucilia caesar*. Further information on the host list of *Alysia* is contained in the publications of Altson¹ and Myers.¹⁵

The host list of *Mormoniella vitripennis* is very long, but a good representative selection is given by Parker & Thompson.¹⁷ *Aspilota nervosa* is recorded by the writer from *Aphiochaeta* sp. for the first time.

4. Hibernation.

Alysia manducator and *Aphaereta minuta* hibernate as full-grown larvae in the puparia of their hosts. If the host hibernates in the larval stage, e.g., *Lucilia sericata*, then pupation is induced by "parasitism" before the parasite larva has completed its development (Holdaway & Evans¹¹). *Mormoniella vitripennis* hibernates as a larva.

In *Alysia* the larva spins a strong silken cocoon, lining the wall of the puparium, but the larvae of *Aphaereta*, usually 6-8 in a puparium, only emit a few strands of silk. No sign of any production of silk by the larvae of *Aspilota* has been found.

5. Emergence.

Graham-Smith⁹ has described the emergence of *Alysia manducator*, which cuts off the anterior cap of the host puparium with its peculiar mandibles. Occasionally emergence takes place from the posterior end. The adults of *Aphaereta* emerge by a single hole, the position of which varies greatly. All do not emerge at the same time; usually after the first emergence has taken place several unpigmented pupae remain, or even a prepupa or larva. *Mormoniella* emerges from one hole, but less frequently from two (Parker & Thompson¹⁷). Defaecation takes place before emergence in *Alysia* and *Mormoniella*, but after emergence in *Aphaereta*. In the case of *Alysia* defaecation normally takes place in the adult stage just before emergence, but in *Mormoniella* it is the larva which defaecates, just at the onset of the prepupal stage.

6. Oviposition by *Aphaereta minuta* and *Alysia manducator*.

Ovipositing females are easily handled and, unless disturbed, show no inclination to leave meat containing larvae until, after ovipositing in about ten larvae, they begin to show signs of restlessness. Unless hosts are numerous they will then very

soon leave the meat. *Aphaereta minuta* oviposits in first and early second instar larvae. Feeding at oviposition punctures, which has been recorded for some Braconids, has not been observed in this species, nor in *Alysia manducator*. As oviposition has been observed on numerous occasions in detail through a binocular microscope, it seems probable that feeding at oviposition punctures does not occur in these species. Further, it seems unlikely that opportunity for such feeding would occur under field conditions, for the mass of writhing larvae in carrion would soon obliterate recently parasitised individuals. The parasite, once having inserted its ovipositor, retains possession of the larva despite the movements of the writhing substratum of larvae, even though some of the latter actually crawl between it and its prey. Myers¹⁵ records that *Alysia* can oviposit through the skin and hair of a small mammal; *Aphaereta* will also oviposit through a layer of meat, burying its ovipositor to the fullest extent in order to reach hidden larvae. The female *Aphaereta* spends a considerable amount of time cleaning off the filth that accumulates on it during its activities.

At the first attempt to observe oviposition, larvae on stale meat were exposed to the parasites, but the interval between each act of oviposition was long. Fresh meat was substituted and oviposition proceeded more rapidly. This observation is of interest, as the adults are attracted to fresh carrion in which larvae suitable for oviposition are to be found.

Myers¹⁵, who made a detailed analysis of the oviposition of *Alysia*, believes that "the suitable bait and perhaps a suitable part of it are located from afar by an olfactory sense seated in the antennae," and that "the individual prey is discovered by touch through the agency of the palp-like organs of the ovipositor sheath." Further, in 1929 the same author¹⁶ writes "as indicating the tremendous role which olfaction plays in oviposition, it may be mentioned here that when I visited him in Western Australia in 1927, Mr. L. J. Newman had had no success in parasitising *Chrysomya albiceps* with *Alysia*. In discussing his technique we found that he had, not unreasonably, since the work was done in his office, washed the maggots thoroughly before presenting them to *Alysia*. When he gave this up, parasitism took place with no further trouble."

Close observation of oviposition in *Aphaereta minuta* seems to indicate that in this species, sense organs present in the tarsi play an important role in oviposition. These sensory organs are no doubt tactile in nature but whether they function also to some extent as contact chemical sense-organs or whether such organs also exist is at present undecided. Minnich¹³ found contact chemical sense-organs in the tarsi of Muscid flies. Suitability for oviposition of a host larva moving over the surface of the meat seems to be judged by a light tapping of the tarsi on the larva before the ovipositor is inserted. When the parasite stands astride the larva, the ovipositor is usually inserted at the first attempt. If however, as is often the case, the larva is to one side, or in front, of the ovipositor, then many ineffectual attempts may be made before success is achieved or the larva escapes unscathed. Sometimes a parasite, while following a larva and tapping it with the fore-tarsi, will make unsuccessful attempts at oviposition until with an extra effort it pierces the larva in the region round the posterior spiracles. The role played by the palpi in choosing or rejecting a larva in these circumstances seems non-existent, since the larva is chosen or rejected before the palpi are brought into use. A parasite seems to sense the presence of larvae separated from it by a layer of meat by the vibrations set up by their movements in the meat. In this case also the palpi do not come into contact with the larvae which are parasitised, since they do not penetrate the meat but are bent double underneath the abdomen. Altson¹ notes with regard to *Alysia* that motionless maggots are passed over by ovipositing females.

It would appear then that, as regards *Aphaereta*, while olfaction is no doubt of great importance as a preliminary to oviposition, the sense of touch either through

actual contact or movement is important in the final stages of oviposition, and further, that this sense is located in the tarsi rather than in the palpi. Observations on *Alysia*, suggest that in this parasite also, sense-organs of touch situated in the tarsi are important in oviposition. Direct observation of the oviposition of *Alysia* in a host larva moving at large over a piece of meat does not aid in distinguishing the roles played by the tarsi and palpi respectively, because *Alysia* is smaller than the larva to be parasitised and in consequence has to mount upon the back of the larva in order to oviposit. Thus, in these circumstances the tarsi must come into contact with the larva before oviposition can be attempted, even though they play no part in the selection of the larva. However, Myers¹⁵ observed that *Alysia* can oviposit through the skin of a small mammal and during this study it was noted that *Alysia* also oviposits in larvae separated from it by a layer of meat. In this case, as in the similar case of *Aphaereta*, the palpi do not come into contact with the larva but are bent between the abdomen and the meat. Here again the evidence does not support the idea that the individual prey is discovered by touch through the agency of the palpi, but rather that hidden larvae are found by means of sense-organs present in the tarsi. These sense-organs detect movements in the meat caused by the moving larvae.

After the female *Aphaereta* has found a suitable larva, the tip of the abdomen is bent downwards until the tips of the valvulae and of the palpi come into contact with the integument of the larva. By means of the downward pressure of the abdomen and by rotary movements of the sclerites composing the ovipositor, the valvulae pierce the integument, while the palpi bend under the pressure of the abdomen, becoming horseshoe-shaped. Sometimes the tips of the palpi slip away from the point of insertion of the valvulae and lie parallel to the integument. This bending of the palpi seems to have a steadying action on the valvulae. The valvulae are pushed well into the haemocoel of the host.

Directly the valvulae have pierced the integument, the larva, without struggling, usually stretches itself to its fullest extent and then lies limp. In some individuals pierced in the posterior end, the head may keep up a constant side to side movement, in others some segments may exhibit contractions, and in a few a faint struggling is maintained all the time; rarely, the larva still moves on, dragging the parasite along with it. In limp individuals the heart stops beating as soon as the larva is fully extended. The parasite now remains quite still, and after an interval of about fifteen seconds the posterior abdominal segments commence a series of quivering movements alternating with still periods. It may be that each of these movements signals the passage of an egg down the ovipositor.

Withdrawal of the valvulae is brought about by an upward jerk of the abdomen aided by the straightening of the palpi due to their elasticity. If the palpi have remained horizontal, a bigger jerk has to be given to extricate the valvulae, and sometimes the parasite seems to experience great difficulty in doing so. The evidence obtained during this study shows that the role of the palpi in oviposition is mechanical rather than sensorial. Altson¹ has described the presence of a wiping pad on the basal area of the palpi of *Alysia manducator*.

Great variation is shown in the recovery of host larvae after oviposition. The larva may begin moving before oviposition has finished and drag the parasite along with it, it may show muscular contractions before oviposition has finished and move away immediately the valvulae are withdrawn, or it may lie motionless for a variable time, up to three minutes. Following oviposition the first signs of recovery of the host larvae are a few muscular contractions; these begin in the segment pierced and pass slowly to the extremities, when contractions are general throughout the body, the larva moves slowly away and soon becomes normal. The first visible movements begin when muscular contraction becomes general. Even though a

larva is motionless, examination by transmitted light shows that peristalsis of the alimentary canal persists. Oviposition by *Aspilota nervosa* was not observed in great detail, but in general characteristics it appears to resemble that of *Aphaereta*.

Myers¹⁵ has described in considerable detail the oviposition of *Alysia manducator*. Upon encountering a larva the *Alysia* female in general adopts a straddling position. The larva now commences to struggle, and its struggles become more violent once the ovipositor has pierced the cuticle. The writhings cease rather suddenly and the larva lies still, usually much contracted, while the parasite lays an egg. The paralysis of the larva is caused by the injection of a secretion from the poison glands of the parasite. When parasites are removed from their respective larvae immediately the latter ceases to struggle, rarely is any progeny recovered. After withdrawal of the ovipositor, the victim continues motionless for a variable time before commencing to wriggle almost as violently as during the attack. None of this violent wriggling is observed in larvae attacked by *Aphaereta*.

7. The Effect of Parasitism on the Pupation of the Host.

In a communication to "Nature," Holdaway & Evans¹¹ discussed the effect of parasitism in the field by *Alysia manducator* and *Aphaereta minuta* on larvae of *Lucilia sericata* which are ready to hibernate. It was shown that when pupation had nearly ceased, the percentage parasitism from puparia was high, *i.e.* 88.4 per cent., while the percentage parasitism from the numerous remaining larvae was very low, *i.e.* 2.7 per cent. This was confirmed by further observations. It was concluded "that retardation by low temperatures of the physiological events normally leading to pupation may be overcome by a stimulus contributed by parasitism." The suggestion was put forward that this stimulus might be contributed by the substance injected by the parasite causing temporary paralysis of the host prior to oviposition. Should this suggestion be correct, it would account for the fact that not all the puparia examined yielded parasites, for incomplete acts of oviposition are common and there is a certain percentage of mortality in the egg stage.

Lack of suitable artificial conditions for low temperature studies have up to the present prevented experimental work to test the validity of the above hypothesis. However, observation made at higher temperatures, approximately 25 C., have indicated the necessity for distinguishing between a "stimulus to pupation" at temperatures at which pupation does not normally occur and an "acceleration of pupation" at temperatures at which pupation normally occurs. In the latter case "acceleration of pupation" would mean a reduction of the prepupal period at temperatures at which pupation normally occurs. Actually at non-hibernation temperatures, parasitism slightly prolongs the prepupal period, as will be seen from the following results obtained from larvae submitted to three differing treatments respectively:—

- (a) Larvae completely parasitised.
- (b) Larvae partly parasitised (*i.e.* the parasite was removed from the host immediately the larva ceased its writhing and before the passage of an egg). Dissection carried out 24 hours after pupation demonstrated the presence or absence of parasite eggs or larvae.
- (c) Larvae unparasitised (for control).

The material used consisted of female *Alysia manducator* and full-grown larvae of both *Lucilia sericata* and *Calliphora erythrocephala*. The following table gives the results of an experiment using twenty full-grown larvae of *C. erythrocephala* for each treatment. Environmental conditions were the same for all batches.

These results do not appear to support the hypothesis quoted above. In view of certain considerations set out immediately below, the writer does not believe that the above experiment invalidates the hypothesis put forward.

TABLE I.

Treatment	...	...	...	...	...	a.	b.	c.
Mean prepupal period in days	...	...	...	...	...	3.0*	3.0	2.5
No. of parasite eggs or larvae demonstrated by dissection	...	...	...	...	...	19	0	—

* One individual took 4.5 days.

The physiological constitution of full-grown larvae about to hibernate is, in all probability, very different from that of larvae at higher temperatures which proceed to pupate without larval hibernation. Especially would this be so in regard to the body fluids. Robinson²⁰ has shown in the cold-hardy Saturniid moth, *Callosamia promethea*, that the proportion of bound water to free water changes when the insect is subjected to low temperatures. The researches of Bataillon², Cousin⁵ and Townsend²², show that pupation is intimately associated with the water relations of an insect. Thus, it is probable that in parasitism at hibernation temperatures and in parasitism at non-hibernation temperatures we have a stimulus acting on an insect in two widely differing physiological states. It is, perhaps, not surprising then that parasitism should under one set of conditions cause a slight increase in length of the prepupal period, while under another set of conditions it should result in bringing to cessation a condition which normally would have continued almost indefinitely without a rise in temperature.

8. The Female Reproductive System.

The chief point of interest in the newly emerged Braconid females studied is the provision of a large store of eggs ready for deposition after a short maturation period (fig. 1, a). Both *Alysia* and *Aphaereta* are active workers while ovipositing, but

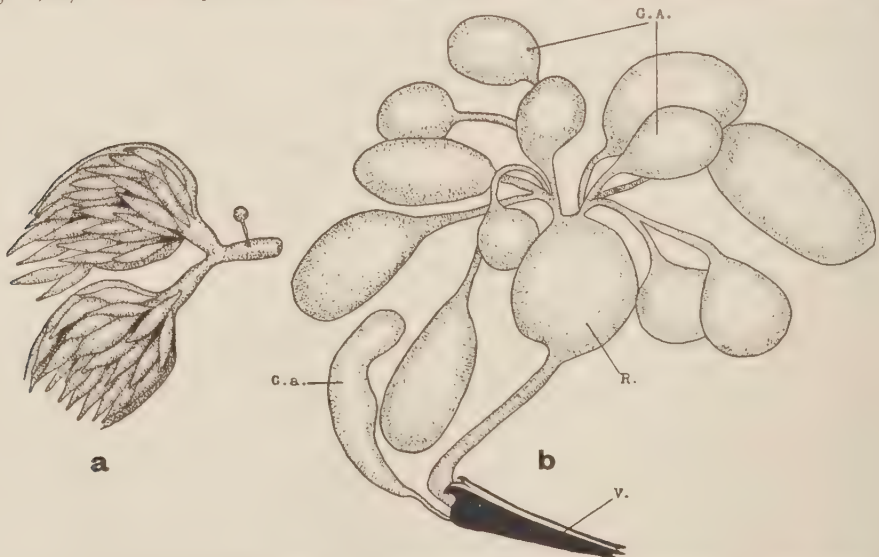


Fig. 1. *Aphaereta minuta*, Nees: a, reproductive system of female, x 20; b, poison gland system, x 30; G.A., acid gland; G.a., alkaline gland; R., reservoir; V., ventral valvulae.

this does not seem to be the case with *Aspilota*. This species however was not studied in sufficient detail to compare its rate of oviposition with that of the other species. In *Aphaereta*, that portion of each ovariole proximal to the oviduct is greatly distended and filled with large numbers of tightly packed eggs. Rarely are all these eggs deposited (Graham-Smith¹⁰). Each ovary consists of two ovarioles. The same type of ovary is present in *Alysia* and *Aspilota*. Each ovary of a freshly emerged *Mormoniella* female consists of four ovarioles, but there is no great storage of eggs such as has been observed in the Braconids. Near the oviduct are found a few fully grown eggs, then progressively smaller ones, until the germarium is reached. Further reserves are found in the germaria, which are much elongated in all four species.

9. The Poison Gland System.

The poison gland system of *Aphaereta minuta* (fig. 1, b) consists of the usual two glands, the alkaline gland being small and tubular, and the acid gland well

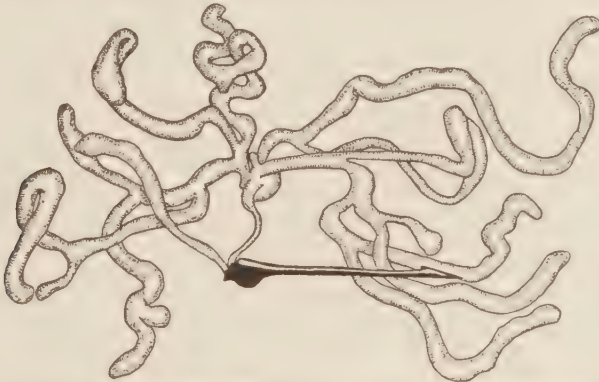


Fig. 2. *Alysia manducator*, Panz.: poisoning land system, x 20.

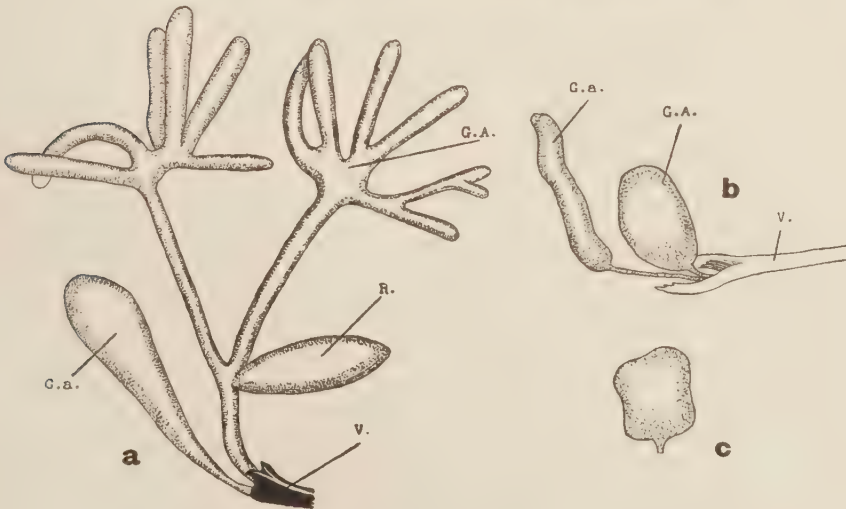


Fig. 3. a, poison gland system of *Aspilota nervosa*, Hal. x 30; b, poison gland system of *Mormoniella vitripennis* (lateral view) x 100; c, acid gland of *M. vitripennis* (posterior view x 100); G.A., acid gland; G.a., alkaline gland; R., reservoir; V., ventral valvulae.

developed and complex. The secretory portion of the latter is concentrated in a number of capsules averaging twelve, six on each side. The ducts from each group of capsules unite together to form a common duct and each common duct opens directly into a muscular reservoir. From this reservoir runs a fine duct opening ventrally on the fused inner valvulae (*gorgeret* of Carlet⁴) of the ovipositor, just posterior to the opening of the alkaline gland. A rather different type of acid gland is present in *Alysia* (fig. 2), the chief difference being that the secretory tissue consists of two groups of dichotomously branched tubules, each group opening by a separate duct into the reservoir. The acid gland of *Aspilota* (fig. 3, *a*) presents an interesting stage intermediate between that of *Aphaereta* and *Alysia*. The secretory tissue is present in two groups of six short tubules of which one, two or three may be branched. A different type of system altogether is present in *Mormoniella* (fig. 3, *b*, *c*); it is much reduced compared with that of the Braconids, the alkaline gland is larger than the acid gland, which is small and almost cubical and the duct of which is greatly reduced in length. A reservoir is not present. The reduced condition of the poison gland system in *Mormoniella* is no doubt correlated with the fact that, as it is a pupal parasite, there is no necessity for paralysing its host.

10. Description of the Egg in the Species Studied.

In the four species studied, the freshly laid egg is smallest in *Aphaereta*, measuring 0.20 mm. by 0.05 mm.* (fig. 4, *a*). It is ellipsoidal in shape with both poles prolonged, greatly resembling Diatoms of the genus *Navicula*. The egg of *Alysia*

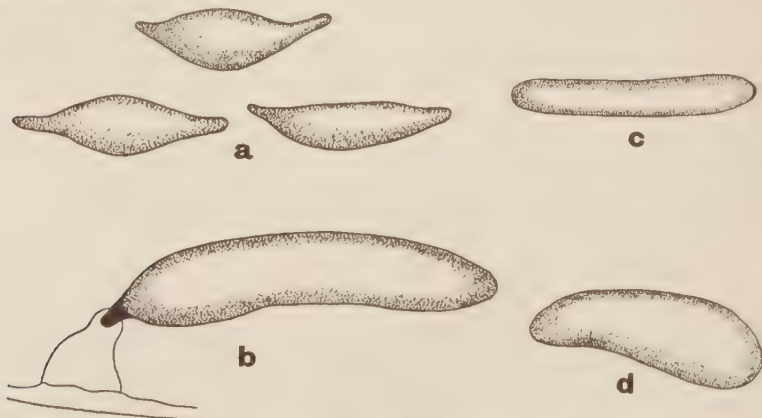


Fig. 4. Eggs of; —*a*, *Aphaereta minuta*, dissected from ovary, 0.20 mm. \times 0.05 mm.; *b*, *Alysia manducator*, 22 hours old, attached to cuticle of host, 0.56 mm. \times 0.10 mm.; *c*, *Aspilota nervosa*, just laid, 0.36 mm. \times 0.05 mm.; *d*, *Mormoniella vitripennis*, just laid, 0.33 mm. \times 0.12 mm.

(fig. 4, *b*) is cylindrical and slightly arched, with an anterior projection of a chorionic nature; its dimensions are 0.54 mm. by 0.1 mm. In *Aspilota* the egg (fig. 4, *c*) resembles that of *Alysia* with the difference that a chorionic cone is absent, the anterior end being only slightly thickened. Its measurements are 0.36 mm. by 0.05 mm. *Mormoniella vitripennis* lays a pear-shaped egg (fig. 4, *d*) with its major axis slightly curved, 0.33 mm. long and with an average diameter of 0.12 mm. *Aphaereta minuta* and *Aspilota nervosa* always lay their eggs free in the haemocoel of the host, and this is often the case with *Alysia manducator*. More usually however (75 per cent.) the egg of *Alysia* is attached to the cuticle of the host by its anterior

* The measurements given have been obtained by means of an ocular micrometer in the case of small objects, *i.e.*, eggs, or with a pair of vernier callipers in the case of large objects, *i.e.*, puparia.

projection, which is held by an internal cone of a cuticular nature formed at the oviposition puncture. This cone may be produced by irritation due to the anterior cone of the egg rubbing against the oviposition puncture. The cone is dark brown in colour and shows up on the white cuticle of the host, aiding in locating the position of the egg. The fate of eggs attached in this way is interesting. Cousin⁶ has shown that the prepupal period of larvae of *Lucilia sericata* is lengthened if the larvae are underfed. If the larva in which the egg is laid is not fully fed, the egg may hatch before pupation takes place and larval development proceeds in the host larva; on the other hand if the host larva is fully fed when parasitised, the puparium may be formed before hatching takes place; the egg is thus withdrawn from the haemocoel and comes to lie between the puparium and the pupa. The eggs of *Mormoniella vitripennis* are laid in the space between the puparium and the pupa, being roughly arranged in a circle around the point of insertion of the ovipositor.

It is an interesting point that all eggs measured immediately after oviposition, or when dissected from the ovaries, are always much wider than the bore of the ovipositor through which they pass. The facility with which the eggs may be handled would seem to be due to the toughness and elasticity of the chorion, which latter fact no doubt accounts for their being able to pass down the ovipositor. Genieys⁸ has recorded that in the case of the ectoparasite, *Habrobracon brevicornis*, the egg when it issues from the ovipositor is viscous. The eggs of the three species of Braconids are more easily handled than those of *M. vitripennis*, indicating a stronger chorion. The reason for this stronger chorion is evident when we compare the habitat of these two groups. The eggs of the Braconids are subjected during their development to the constant movements of the viscera of the host, whilst the eggs of *Mormoniella* lying between the motionless pupa and the puparium remain undisturbed. The number of eggs laid by *Aphaereta* varies between ten to fifteen in a host larva; by *Alysia*, one is normally laid, but several times two have been found; while in *Aspilota*, never has more than one been found. *Mormoniella* deposits from ten to twenty eggs at each act of oviposition.

11. The Development of *Aphaereta minuta*.

The following description applies to material reared at a mean temperature of 17.5°C., varying daily between 15° and 20°; the hosts were young first instar larvae of *Calliphora erythrocephala*. A greater proportion of the total development of this species takes place in the egg than occurs in the egg of the other species studied, the egg period lasting for nine days in a developmental period of twelve days. This lengthy egg period is associated with a great increase in volume of the egg, a considerable portion of the nourishment of the parasite taking place in this stage.

Calculating the volume of the egg by a graphical method* we find that the new-laid eggs have a mean volume of 0.0002 cubic mm. Eggs ready to hatch have a mean volume of 0.58 cubic mm. or an increase of 2,900 times their initial volume. If the volumes of the egg from day to day are plotted, an interesting graph is obtained. At first there is a steady increase in volume, lasting until the end of the third day. The rate of increase in volume is now accelerated rapidly. The great increase in volume of the egg commences on the fourth day, when the individual systems are being formed. Until this the developmental processes occurring in the egg have been principally cell division and cell differentiation, but now, on the fourth day, tissue formation commences and the egg rapidly increases in size.

* An accurate large scale drawing of the egg is made on graph paper and its area determined by counting the number of squares inside its outline. Half the area is divided by the length of the egg. This gives us the width of a rectangle which, rotated about its length, describes a cylinder equal in volume to that of the egg. The volume of the cylinder is now determined from the formulae $\pi r^2 l$.

The trophamnion is formed two days after laying, and on the third day the embryo is distinctly visible, having the shape of a W (fig. 5, *a*). The embryo remains in this form for nearly two days, during which time the viscera begin to develop. At the end of the fifth day the shape changes, the embryo becoming curved, with its anterior and posterior extremities apposed to each other. Consequent upon further growth, the embryo begins to straighten out and the individual internal systems can be distinguished (fig. 5, *b*). The head and thirteen body segments can now be seen; the head is larger than any of the other segments, and the mouth and anus are visible. The large brain and suboesophageal ganglion can be clearly seen, together with a ventral nerve cord of three thoracic and eight well differentiated abdominal ganglia. The alimentary canal runs direct from mouth to anus, and the closed junction of the mesenteron and proctodaeum can be distinctly seen between the 8th and 9th abdominal segments. One pair of malpighian tubules is present.

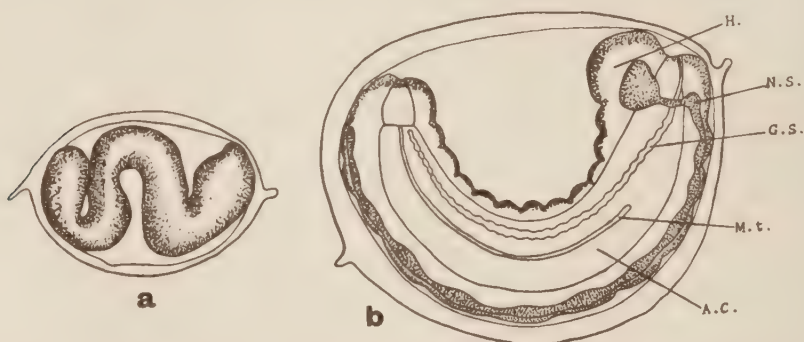


Fig. 5. *Aphaereta minuta*: *a*, embryo 4 days old, 3.8 mm. x 2.6 mm.; *b*, embryo 6 days old, 5.7 mm. x 4.8 mm.; H, head; N.S., nervous system; M.t., malpighian tubule; G.S., salivary gland; A.C., alimentary canal.

By the seventh day the host larva has migrated from its food and has entered upon the prepupal stage; its plasma is no longer clear but is milky, owing to the beginning of disintegration of the fat-body. The parasite eggs are still unhatched.

On the eighth day the chorion appears to be pigmented but this is really the deposition of a brown substance on the surface of the egg. The trophamnion is absorbed just before hatching, which takes place when the puparium of the host is formed. The following volumes relate to individuals dissected from two freshly formed or "white" puparia: six nearly round eggs, mean volume 0.50 mm.; eight eggs ready to hatch, the embryos partly straightened out, mean volume 0.58 mm.; and four larvae just hatched mean volume 0.54 mm. Dissection at the same time of pigmented puparia showed that all the eggs had hatched, while only eggs were present in prepupae.

Nourishment for the rapidly growing embryo is obtained by diffusion through the chorion. The effect on the host of this drain on its resources is threefold: (*a*) the duration of larval life is increased by twelve hours in an average developmental period of sixty hours; (*b*) its size lags behind that of its unparasitised companions, parasitised puparia having a mean volume of 60 mm., compared with 80 mm. in normal puparia; (*c*) the larva is enfeebled, and at the time of migration some individuals could not climb out of the porcelain breeding jar 6 cm. high, a feat presenting no difficulty to unparasitised larvae.

The fully developed eggs occupy about one-tenth of the volume of the host puparium. When the parasite larvae have hatched, the fat-body of the host is

small and the larvae take up so much space that further development of the pupa ceases. In normal puparia, two days old, the imaginal buds have everted, but this never takes place in parasitised puparia.

The head of the first instar larva is very simple in structure; the trophi consist solely of a pair of sharp unpigmented mandibles; a pair of antennae and post-antennal organs are present. No respiratory system is developed. A pair of salivary glands run along the side of the distended mesenteron above the malpighian tubules to the 9th abdominal segment.

The main point of interest in the second instar is the nature of the sensory organs (fig. 6, *a*). A pair of these is present on each side of the head, *viz.* a large circular differentiation of the integument bearing a small papilla and a more elongate differentiation without a papilla lying slightly below and behind the former. A study of the brain shows that the former differentiation is supplied by a nerve given off near the para-oesophageal commissures, and that the latter differentiation is supplied by the main mass of the brain. It is then probable that the circular structure is the antenna and that the more elongated structure is the vestigial larval ocellar system. However, no vestiges of an ocellar system have been found in the larvae of the other *ALYSIINAE* studied, so that the post-antennal organ may be a sensory structure peculiar to *Aphaereta*.

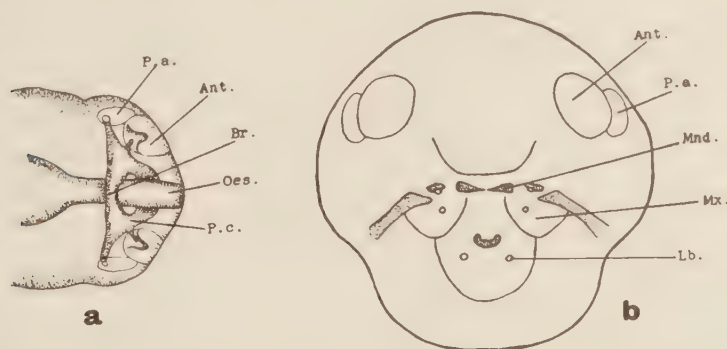


Fig. 6. *Aphaereta minuta*: *a*, cephalic sense-organs (dorsal view) of 2nd instar larva $\times 57.5$; *b*, head of 3rd instar larva (end view) $\times 85$; *ant*, antennae; *p.a.* post-antennal organs; *oes*, oesophagus; *br*, brain; *p.c.* para-oesophageal commissures; *mnd*, mandible; *mx*, maxilla; *lb*, labium.

The head of the third instar larva is more elaborate than that of the second instar (fig. 6, *b*). The trophi are more complex, the mandibles being stronger and pigmented; the maxillae are represented by a pair of papillae, and the labium by a pair of papillae and an unpaired pigmented sclerite bearing the opening of the common salivary duct. The strengthening bars of the head-capsule, complex in some Braconids, are here reduced to a pair of horizontal rods. The respiratory system is now evident and consists of paired lateral trunks, each with a prothoracic and eight abdominal spiracles.

The entire contents of the host puparium are consumed, excepting the cephalo-pharyngeal skeleton and the main tracheal trunks. It would appear that all the food of the larvae is imbibed in a liquid state, since the oesophagus in all instars is adapted for sucking, whilst the trophi are too poorly developed and their structure unsuited for chewing or ingesting particles. In addition, the position of the opening of the salivary glands is external to the mouth.

12. The Development of *Alysia manducator*.

The development of *A. manducator* has previously been noticed by Altson¹ who briefly described the egg and the external characters of the three larval instars. The following description applies to material dissected from hosts parasitised as full-grown larvae.

Altson¹ gives 66 hours as the incubation period of the egg in larvae of *Calliphora erythrocephala* at 20°C. At the temperatures reigning during the present study, 17.5°C., and with the same host, just over four days were necessary. There is no great increase in the volume of the egg during the development of the embryo, as has been noticed in *Aphaereta minuta*; the volume of a freshly laid egg is 0.004 cmm. and that of an egg ready to hatch 0.010 cmm. The egg ceases to increase in size if, through being attached to the larval skin, it is withdrawn from the haemocoel on the pupation of the host, but hatching is successful. Compared with the rate of development of the egg in *Aphaereta*, that of *Alysia* is rapid, four days in a minimal development period of thirteen days. Myers¹⁵ gives ten days as the developmental period (until cessation of feeding) in North Essex, England, but does not state the temperatures reigning at the time. As there is such a small



Fig. 7. *Alysia manducator*, head of the 1st instar larva: a, lateral view; b, ventral view; *mnd*, mandible; *G.S.*, salivary gland; *D.S.*, ducts of salivary glands; *S.p.*, sensory process.

increase in volume throughout the egg stage, compared with that found in *Aphaereta*, it seems improbable that there would be any large or rapid changes in the rate of increase. The available data show that the rate of increase in volume is at its maximum when tissue building is beginning, as was shown in the case of the embryonic development of *Aphaereta*. At the close of the second day, while the host is still in the prepupal stage, the embryo is well developed and surrounded by the trophamnion, the head is distinctly visible, the three thoracic segments distinct, and the beginning of segmentation in the abdomen is evident. The internal organs are now beginning to form. The host pupates on the third day. Segmentation of the embryo is now complete, showing head, three thoracic and ten abdominal segments. On the fourth day the embryo is fully formed and moving, ready to hatch.

The head of the first instar larva is better developed than the head in the corresponding stage in *Aphaereta* (fig. 7, a, b). The vestiges of a head-capsule can be recognised in a differentiated plate which forms the ventral and lateral portions of the head, but does not cover the dorsal, or frontal regions. This plate is bounded by a thickened pigmented rim, with whose anterior extremities the mandibles articulate. The latter are strong and pigmented, with a broad base and curved pointed

apex. Just anterior to the mandibles on each side of the labrum lies a pair of projections surmounted by a very small papilla. Their exact nature is not understood. They may possibly be the antennae, but no indication of a nerve from the brain to them could be traced. Genieys⁷ has described in the third instar larva of an Eviid, *Zeuxevania splendidula*, Costa, a pair of papillae lying on each side of the labrum, bearing eight sensory organs. It may be that the projections described are of a similar nature. Posterior to the mandibles is found another pair of projections which may be rudiments of the maxillae or labium. There is a prominent pair of papillae on the ventral surface of the head. No definite traces of antennae are present. On the head and each of the thoracic segments and abdominal segments 1-9 are two pair of small papillae, one pair dorsally and one pair ventrally placed (fig. 8, a). These are not of the bristle type figured by Genieys⁸ for *Habrobracon brevicornis* and by Seurat²¹ for an ectoparasitic Chalcid, *Torymus propinquus*.

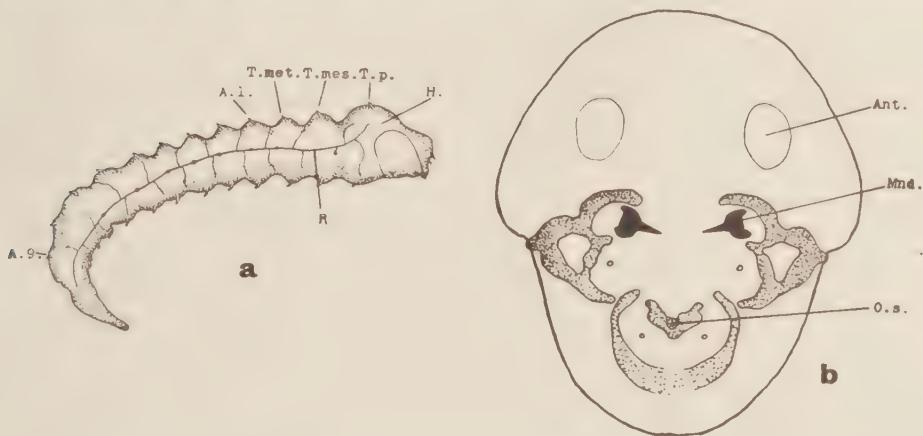


Fig. 8. *Alysia manducator*: a, 1st instar larva 5 days old $\times 62.5$; H, head; T.p, T.mes, T.met, pro-meso-meta-thorax; A.1, A.9, abdominal segments 1 and 9; R, respiratory system. b, head of 3rd instar larva (end view) $\times 100$; Ant, antenna; Mnd, mandible; O.S, opening of salivary duct.

Foerster, but are hollow, with a protoplasmic core (whether of epidermal or neural nature was not determined). Those present on the head are of a more spiny nature than those on the thorax and abdomen. The so-called "respiratory organ" is a posteriorly directed ventral prolongation of the tenth abdominal segment and is not the evaginated proctodaeum described for some Braconids.

The respiratory system consists of paired lateral trunks, with a pair of open spiracles on the mesothorax and stigmatic cords on the metathorax and abdominal segments 1-6. The alimentary canal is simple, bearing a pair of malpighian tubules running from the proctodaeum over the dorsal surface of the mesenteron into the thorax. The salivary glands are well developed and occupy a large portion of the prothorax; thinning posteriorly, they run beneath the mesenteron to the seventh abdominal segment. The salivary ducts have a common opening in the mouth. By the third day of larval life the salivary glands have increased greatly in size and now lie alongside the mesenteron. The malpighian tubules lie above the salivary glands, a condition the reverse of that found in *Aphaereta*. The heart is well developed and runs from the posterior abdominal segment to the prothorax, presenting a slight dilatation in every segment. The brain is small but the oesophageal ganglion is well developed. The ventral nerve-cord stretches back to the eighth abdominal segment and shows a slight thickening, representing the ganglion in each segment.

In the second instar larva the nature of the head-capsule differs greatly from that of the first instar larva. The cuticle of the head is similar to that of the post-cephalic segments and is not strengthened by bars. The mouth is no longer ventral but terminal, and the mandibles are simple and unpigmented, with their apices widely separate. The antennae are now prominent. The respiratory organ is no longer present, but a short projection of a similar nature is present dorsal to the anus. A tracheal respiratory system is absent. The brain is proportionately larger than in the first instar and lies partly in the head and partly in the prothorax. The relative positions of the malpighian tubules and the salivary glands have changed, being the reverse of that found in the first instar, and are now similar to the condition found in *Aphaereta*.

The structure of the head and that of the respiratory system are the chief points worthy of note in the third instar (fig. 8, *b*). The trophi are represented by strong mandibles, as well chitinated as those of the first instar, but their apices do not meet. Two small papillae mark the vestiges of the maxillae. The labium is bounded by a horseshoe-shaped sclerite enclosing two papillae and a central unpaired sclerite bearing the opening of the salivary glands. The head framework, so poorly developed in *Aphaereta*, is here well developed and resembles that of *Habrobracon brevicornis*. The respiratory system shows well developed paired lateral trunks with numerous secondary branches. Open spiracles are present on the pro- and meso-thorax and abdominal segments 1-8. There appears to be some variation in the number and position of the spiracles on the thorax, Morgan¹⁴ records one pair present on the prothorax and Altson¹ one pair situated on the mesothorax.

The first instar lasts for a minimum period of from four to five days, but it is difficult to give an accurate estimation of the lengths of the second and third instars owing to the great variation in rate of development in different individuals. This variation may be partly explained by the effect of parasitism on the host. The pupation of fully grown parasitised larvae is retarded in varying degrees; most larvae pupate soon after the normal prepupal period of two and a half days, while for others this period may be lengthened to as much as ten days. This prolongation of the prepupal period has a very definite retarding effect on the rate of development of the parasite larva, perhaps through a nutritional factor, as the fat-body of the host does not begin to disintegrate until one to two days after pupation. In an experimental batch under observation, on the day when the first full-grown parasite larva was found with a volume of 67 cmm. all stages from half-grown second instar larvae upwards were found in other puparia; the volume of the smallest was 7.25 cmm. One can thus understand, at least to some extent, the reason for a period of roughly sixty days elapsing between the first and last emergence of the adults as recorded by Graham-Smith.⁹ This writer also noticed that if two eggs are laid in one host only one adult parasite emerges. Observations on this point show that both eggs hatch and the larvae develop until the contents of the puparium are consumed. One larva then devours its companion.

13. Discussion on the Ectoparasitic Characteristics of *Alysia manducator*.

As is well known the BRACONIDAE are either ecto- or endo-parasites. *Aphaereta minuta*, *Alysia manducator*, and *Aspilota nervosa* obviously belong to the latter group, but in *Alysia* several characters are to be found which suggest that the acquirement of an endoparasitic life is comparatively recent, or at least that it has not yet reached such an advanced stage of endoparasitism as is shown by the other two genera. These characteristics are:—

- (1) The frequent attachment of the egg to the cuticle of the host and its successful development even when withdrawn from the haemocoel.

- (2) The chorionic process at the anterior pole of the egg, so well developed in *Alysia*, is reduced to a slight thickening in *Aspilota* and has disappeared in *Aphaereta*.
- (3) The presence in the first instar larvae of an open respiratory system. That this is in the process of degeneration from the typical holopneustic type is shown by the presence of stigmatic cords in the mesothorax and abdominal segments 1-6. In the ectoparasitic *Habrobracon brevicornis* open spiracles are present on the mesothorax and abdominal segments 1-8. In the endoparasites *Aphaereta* and *Aspilota* we find in the former no tracheal respiratory system whilst in the latter it is restricted to a pair of fine lateral trunks in the metathorax and abdominal segments 1-3, with no spiracles but stigmatic cords occurring in the metathorax and first and second abdominal segments.
- (4) In the first instar, the ventral position of the mouth and the structure of the mandibles are adapted for piercing the integument of the host. Genieys⁸ has figured the trophi of a first instar larva of the ectoparasitic *H. brevicornis*, and although no definite statement is made in the text, it would appear from the figure that the trophi are ventral in position. The trophi of the ectoparasitic *Mormoniella vitripennis* are also ventral in position. Throughout the larval stages of *Aphaereta* the mandibles are similar in structure to those of the second instar *Alysia* larva, but in the first and third instars of the latter the mandibles are of a very different type, seemingly more adapted to piercing.
- (5) The papillae found on the thoracic and abdominal segments of the first instar larva are suggestive of a locomotory significance.
- (6) In the third instar larva, the complex head framework resembling that of the ectoparasitic *Habrobracon brevicornis*, is not reduced as in *Aphaereta* and *Aspilota*.
- (7) The full-grown larvae of *H. brevicornis* spin a strong silken cocoon in which to pupate (Genieys⁸). The fully developed larvae of *Alysia* also spin a strong cocoon, but in *Aphaereta* this cocoon has been reduced to the few strands of silk emitted by the larvae, whilst in *Aspilota* no sign of the cocoon remains.

14. The Development of *Aspilota nervosa*.

The head of the first instar larva is comparatively well developed (fig. 9, *a*); the head-capsule is simple and strengthened by a pair of horizontal bars, the anterior

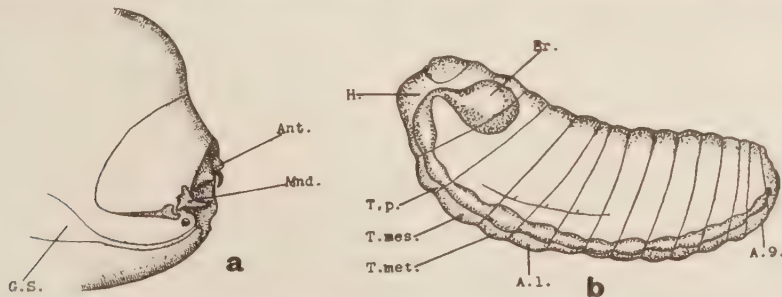


Fig. 9. *Aspilota nervosa*, *a*, head of 1st instar larva (lateral view) $\times 300$: Mnd, mandible; Ant, antennae; G.S, salivary gland. *b*, 1st instar larva $\times 85$: H, head; T.p, T.mes, T.met, pro-meso-meta-thorax; A.1, A.9, abdominal segments 1 and 9; Br, brain.

extremities of which serve as bases of articulation for the mandibles. The faintly pigmented mandibles are strong, slender and slightly curved, with their apices

meeting. Just below the mandibles is a pair of papillae which may represent the maxillae, and below these again is a less well defined pair which may be the vestiges of the labial palps. The opening of the salivary ducts is found just above the latter. The antennae are very well developed. Ten abdominal segments are present. The tracheal respiratory system is restricted to a pair of fine lateral trunks in the metathorax and abdominal segments 1-3. No spiracles are present, but stigmatic cords are found in the metathorax and first and second abdominal segments. The nervous system is very well developed (fig. 9, *b*). The brain is large and occupies the dorsal portion of the head and prothorax, and the ganglia of the ventral nerve cord are well differentiated. Three thoracic and nine abdominal ganglia are present. The salivary glands are well developed and run posteriorly under the mesenteron to the sixth abdominal segment, where they meet the short and stout paired malpighian tubules.

The head of the second instar larva is simple, there are no strengthening bars and the mandibles resemble those of the same stage in *Aphaereta*. In the third instar larva (fig. 10) the mandibles are long and pointed, with overlapping apices. A pair



Fig. 10. *Aspilota nervosa*, trophi of 3rd instar larva (end view): Mnd, mandible; Mx, maxillae; Lb, labium.

of horizontal bars is present, but the bases of the mandibles do not articulate with these but with a band of chitin strengthening the dorsal lip of the mouth. Vestiges of the maxillae and labium are present, but are not so distinct as those of *Aphaereta* and *Alysia*. The respiratory system is developed and consists of paired lateral trunks running the length of the larva and supplying each segment with paired dorsal and ventral tracheae. Open spiracles are present on the prothorax and abdominal segments 1-3; they are connected to the lateral trunks by long tracheae.

The development of the egg and first instar larva takes place during the larval stage of the host, that of the second and third instars inside the host puparium.

15. The Development of *Mormoniella vitripennis*.

At the time when this study was carried out, only virgin females were available for oviposition, so that this description applies to the male sex only. There is no increase in volume of the egg during development, as has been found in *Alysia* and *Aphaereta*. The egg hatches nearly four days after oviposition, and the larva is very much more fragile than the corresponding stage in the other species studied. In general shape the first instar larva differs from that of the Braconids studied (fig. 11, *a*) in being broad across the thorax and tapered posteriorly, rather than cylindrical. Head and thirteen post cephalic segments are present. The head is greatly reduced in size and is strengthened by a chitinous ring, thickened anteriorly, with a transverse bar which marks the posterior border of the mouth, the thinner posterior portion of the ring is internal. The mandibles are curved and pointed,

having broad bases which articulate with the extremities of the transverse bar and a more anterior pair of projections from the ring. There is no trace of either maxillae or labium (fig. 11, *b*). A pair of very small antennae are present. No locomotory bristles are present such as are found in *Habrobracon brevicornis* or *Torymus propinquus*.

The respiratory system consists of paired lateral trunks with four pairs of open spiracles, one pair between the pro- and meso-thorax, the others on abdominal segments 1-3. Altson¹ records thoracic spiracles on the meso- and meta-thorax. Stigmatic cords exist in the metathorax and abdominal segments 4-8. This state is unchanged in the second instar, but in the third all the stigmatic cords except the last pair develop a lumen and are connected with open spiracles. An exactly similar system was found by Seurat²¹ in *Torymus propinquus*. The oesophagus is very fine and opens into a spacious mesenteron. The salivary glands are voluminous and run nearly the length of the larva. Their ducts open by a single canal on the posterior border of the mouth. The paired malpighian tubules extend into the mesothorax. The gonads are visible at the junction of the mesenteron and proctodaeum, and their ducts may be traced to the ventral region of the ninth abdominal segment.

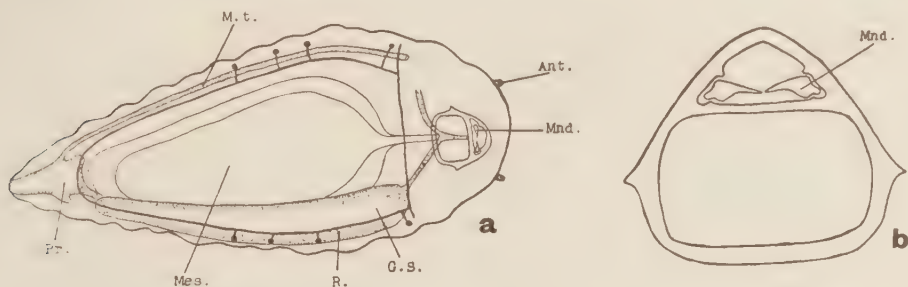


Fig. 11. *a*, 1st instar larva of *Mormoniella vitripennis* (ventral view) $\times 200$; *b*, trophi and strengthening ring of head of 1st instar larva of *M. vitripennis* (ventral view): Ant, antennae; Mnd, mandible; G.S, salivary gland; R, respiratory system; Mes, mesenteron; Pr, proctodaeum; M.t, malpighian tubule.

In the second instar larva the salivary glands are relatively smaller than in the first instar larva. The nervous system consists of a simple brain, pushed backwards into the prothorax by the development of the head muscles used in connection with the sucking oesophagus. The suboesophageal ganglion and the ganglia of the ventral nerve-cord are scarcely differentiated in a thick rod of nervous tissue. The heart is a fine tube, opening widely in the last segment, running along the dorsal surface of the mesenteron and terminating just behind the brain. The structure of the third instar larvae does not differ from that of the first and second instars, except in the case of the respiratory system.

The first instar lasts one day, the second instar two days and the third instar three days, a total developmental period of nearly ten days, at a temperature of 17.5 C. The development of the first and second instars is fairly uniform, but competition for space on the deflated pupa causes variation in size to begin early in the third instar.

16. Discussion on the Adaptations to Endoparasitism found in the Genera, *Alysia*, *Aspilota* and *Aphaereta*.

A comparison of the characteristics exhibited by the larvae of the parasites just discussed with those shown by a truly ectoparasitic larva, such as that of *Habrobracon brevicornis*, described by Genieys⁸, suggests that these species may be

arranged in a series illustrating some effects of the acquisition of an endoparasitic habit on larval structure. This series commencing with a typical ectoparasite, *H. brevicornis*, passes to *Alysia manducator*, an endoparasite showing many apparently ectoparasitic characters; then to *Aspilota nervosa*, an endoparasite with but a few poorly developed ectoparasitic characters; and ends in *Aphaereta minuta*, in which none of the ectoparasitic features present in *Alysia* and *Aspilota* have been found.

The most striking modifications are the following :—

- (a) The loss of accessory locomotory structures, such as the spines and protuberances found in some ectoparasitic larvae, *i.e.* *H. brevicornis* and *Torymus propinquus*. Structures which may have a locomotory significance are present in the first instar larvae of *Alysia manducator* but are completely absent in its later stages and in all stages of the larvae of *Aspilota* and *Aphaereta*.
- (b) The reduction of the trophi, especially in the second instar to a pair of weak mandibles. The first and third instars of *Alysia* and *Aspilota* show comparatively well developed mandibles, whilst the mandibles of the second instar of *Alysia* and *Aspilota* and all the instars of *Aphaereta* are poorly developed.
- (c) Reduction in complexity of the framework of the head-capsule in the third instar larvae. Both *H. brevicornis* and *Alysia* show this structure well developed, but in *Aspilota* and *Aphaereta* only paired horizontal bars are present.
- (d) The gradual disappearance of a tracheal respiratory system in the first instar and its complete disappearance in the second instar of all three endoparasites. *H. brevicornis* possesses a holopneustic system in the three instars. The first instar larva of *Alysia* possesses a propneustic tracheal system, that of *Aspilota* a poorly developed closed tracheal system, while in *Aphaereta* no trace of a tracheal system remains.
- (e) The loss of the cocoon, well developed in *Habrobracon* and in *Alysia*, but absent in *Aspilota* and *Aphaereta*.

17. On the Relative Amounts of Growth Taking Place in the Egg and Larval Stages of *Aphaereta minuta* and *Alysia manducator*.

A schematic representation of the development of the parasites here studied in relation to that of their host, *Calliphora erythrocephala*, is given in fig. 12. The striking point brought out by this diagram is, that by far the greater portion of larval development occurs after pupation of the host. In *Aphaereta minuta* hatching is closely connected with the onset of pupation (p. 394). In *Aspilota nervosa*, the development of the second and third instars occurs after the pupation of the host. The egg of *Alysia manducator* may hatch before pupation of the host, but in this case the development of the first instar larva is retarded. The development depicted by the upper of the two lines given for *A. manducator* (fig. 12) illustrates this condition; the lower line represents development when the egg hatches after the host larva has pupated. Comparison between the development of *Aphaereta minuta* and of *Alysia manducator* shows that in the former the egg-stage occupies actually and relatively a much larger proportion of the ante-pupal period than it does in the latter.

It has been stated above that the egg of *Aphaereta* increases in volume 2,900 times during its development, while that of *Alysia* only doubles its volume. When, however, we compare the ratios of the initial volume of the egg to the final volume

of the full-grown larva in each species, we find them very similar in each species, 1:13,900 in *Aphaereta*, and 1:15,000 in *Alysia*. In other words the relative increase in size from the beginning of the egg-stage to the completion of larval development is similar in the two species. However, of this increase one-fifth takes place in the egg-stage in *Aphaereta*, while in *Alysia* the amount of growth in this stage is negligible.

An analysis of the growth of the larval stage in *Mormoniella vitripennis* and of the egg-stage in *Alysia manducator* shows that the curve representing the increase in volume with time follows very closely the general laws established by Brody & Ragsdale³ for the rate of extra-uterine growth of the cow, by Robertson¹⁹ for the rate of increase in length of annual plants, and by McKendrick & Pai¹² for the multiplication of micro-organisms.

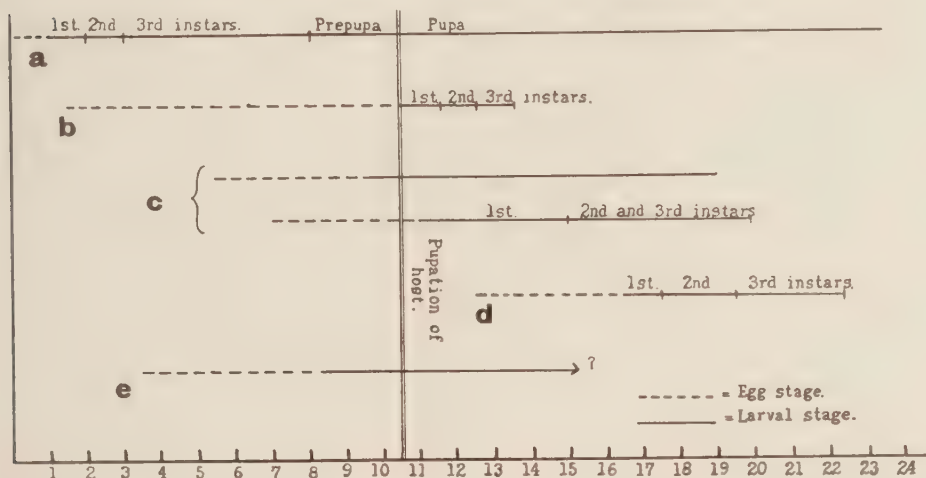


Fig. 12. Diagrammatic representation of the life-histories of the host and parasites studied, at 17°C.: (a) *Calliphora erythrocephala*; (b) *Aphaereta minuta*; (c) *Alysia manducator*; (d) *Mormoniella vitripennis*; (e) *Aspilota nervosa*. Since *Aspilota nervosa* is not a parasite of *C. erythrocephala*, its life-history is only to be considered in relation to the time of pupation of its host.

This evidence leads to the conclusion that part of the functions of growth and nutrition carried on in the larval stage of *Alysia* are performed in the egg-stage of *Aphaereta*. Since the eggs of *Aphaereta* are laid in first and early second instar larvae, the parasite is associated with its host during the latter's early growth metabolism, while in *Alysia* the parasite is not associated with the host until the latter has almost completed its growth and the processes of metamorphosis have begun. The differences in the actual and relative amounts of growth performed in the egg and larval stages of the two species thus appears to be correlated in some way with the different states of the body fluids of the host, and these in turn are dependent on the different types of metabolism in progress within the host at the time of oviposition.

18. Acknowledgments.

This study was carried out under the direction of Dr. F. G. Holdaway, to whom the writer is greatly indebted for his ready and always helpful advice.

Facilities for the work were provided in the Department of Zoology, at the University of Toulouse, France, through the courtesy of Professor A. Lecaillon (late Head of the Department) and of Professor A. Vandel.

The thanks of the writer are due to M. Paul Genieys for his kindness in allowing him to examine numerous unpublished drawings and descriptions of larval Braconids.

19. Summary.

1. The biology and larval morphology of three Alysiine Braconids and one Chalcid, parasites of the pre-imaginal stages of some carrion-infesting Dipterous larvae, are described.
2. The mode of hibernation of the parasites is recorded.
3. The oviposition of *Alysia manducator* and *Aphaereta minuta* is discussed in detail, attention being drawn to the hitherto neglected sense-organs located in the tarsi of these two species and to their importance in the process of oviposition.
4. The differing responses of full-grown *Lucilia sericata* larvae to parasitism by *Alysia manducator* at high and low temperatures are suggested to be due to differences in the physiological states of the host larvae at these temperatures.
5. A comparative study of the three endoparasitic Alysiines suggests that *Alysia manducator* may have reached a state of endoparasitic life relatively later than the other species studied, or at least has not yet reached such an advanced stage of endoparasitic specialisation as have *Aphaereta minuta* and *Aspilota nervosa*.
6. The growth of the egg in *Aphaereta minuta* and *Alysia manducator* and of the larvae of *Mormoniella vitripennis* is discussed.

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ECOLOGY OF THE MOROCCAN LOCUST IN IRAQ AND SYRIA AND THE PREVENTION OF ITS OUTBREAKS.

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(PLATE XII.)

Introduction.

In the spring of 1932 the President of the International Locust Office at Damascus invited me to visit the main breeding areas of the Moroccan Locust (*Locustaurus maroccanus*, Thunbg.) within the territories of the states adhering to that Office, i.e. Turkey, Syria and Iraq, in order to survey the local locust problem and to advise on the best general policy of locust control. The visit represented partly a continuation of the previous season's work in Western Anatolia (Uvarov, 1932) and concerned the great locust area which comprises the south-eastern vilayets of the Turkish Republic, the northern provinces of Syria and northern Iraq.

The voyage was planned to take place at the period when oviposition by locusts usually occurs, and about three weeks in the second half of May and early June were spent in actually touring the areas subject to regular locust invasions in Iraq and Syria. Unfortunately, no arrangements were made for including Southern Turkey in the tour and, therefore, an important section of the area remained unstudied.

While the choice of the period for the ecological investigations proved to be correct, the year was scarcely favourable for reaching very definite conclusions. Locust swarms were numerous and rather widely spread during at least two or three previous years, but the meteorological conditions of the early spring of 1932 were quite exceptional, owing to the practical absence of rains, which caused great mortality amongst young hoppers. I had to deal, therefore, only with the somewhat scattered remnants of swarms formed by surviving hoppers, and it was not easy to decide whether their survival in any given locality was due to chance, or to some favourable ecological conditions peculiar to that locality. The results of my studies must, therefore, be regarded as only preliminary, but they are already sufficient to characterise the Upper Mesopotamian area of the Moroccan Locust and to make practical suggestions as to the general policy of controlling that locust on a rational basis.

Acknowledgments.

I should like to express my gratitude to the Damascus Locust Office and particularly to its President, M. Sureya Bey Effendi, for offering me the opportunity to carry out these investigations. My work in Iraq was greatly facilitated by the perfect local arrangements, and it is my pleasant duty to record my sincere thanks to all those who helped me during my travels: to Anwar Beg Khayyat, Director of Agriculture; to Mr. J. F. Webster, Inspector General of Agriculture; to Mahommed Al Radi, Chief Locust Officer, who sacrificed much of his time and energy in accompanying me personally over the locust areas and whose help in arranging various stages of the voyage was invaluable; and to other members of the Locust Department who were always most helpful and spared no effort to facilitate my survey. My voyage through Northern Syria was made in the pleasant and helpful company of Sobhi Bey Hassibi, Director of the Damascus Locust Office whose extensive knowledge of the country and of the local locust problem was equal only to his eagerness to help in my work, and it is my pleasant duty to thank him for all his kindness. Several members of the agricultural service in Syria, particularly M. T. Ahdab, also placed themselves unreservedly at my disposal and

I am deeply obliged to them, as well as to M. Attala, Director of Agriculture, who made the necessary arrangements for my journey in Syria. To the authorities of the Imperial Institute of Entomology I am obliged for granting me leave of absence for the voyage.

The botanical part of my work was made possible by the willing assistance of Dr. A. Eig, Jerusalem, with whom I had the privilege of discussing my problems before starting the field work, to the obvious advantage of the latter. I have to thank Dr. Eig also for the determination of the plants collected by me without the delay usual in such cases. To another botanist, Mr. E. Guest, Baghdad, I am grateful for helping me to learn some of the typical local plants before going on tour.

Physiography of the Country.

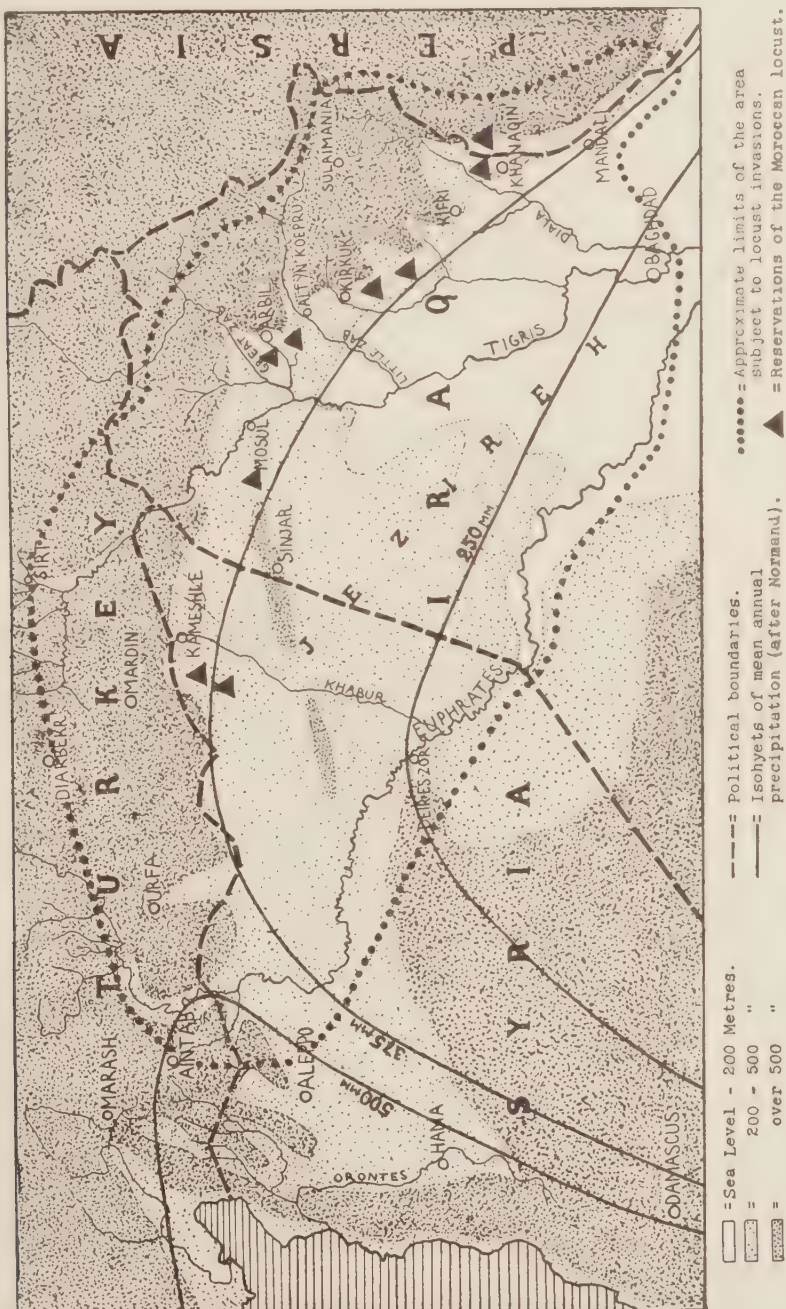
The area under study comprises the whole of Upper Mesopotamia, with the adjoining parts of Syria, Turkey and Persia, and the chief structural features are as follows. On the west, great parallel chains of the Lebanon and the Anti-Lebanon stretch from south to north like a double wall separating the arid hinterland from the Mediterranean Sea. In the north, these chains are interrupted by the valley of the river Orontes beyond which under the name of Giaour Dag, they assume a north-easterly direction and join the Taurus system. That latter system forms the southern rim of the vast plateau of inner Anatolia and lies mainly to the west of the limits of our area, but its offshoots running from west to east enclose that area in the north. From this northern raised border, the country slopes down somewhat gradually southwards. This slope is formed by the southern vilayets (Urfa, Diarbekr, Mardin) of the Turkish Republic, by the northern Syrian districts, and by the western part of the Mosul liwa of Iraq; most of it lies between the two great rivers, Euphrates and Tigris. In the north-east, beyond the river Tigris, the Taurus offshoots merge into the great system of the Zagros, or Kurdish, mountains which soon assume a south-eastward direction, continuing in the south as the Pusht-i-Kuh ranges, already within the Persian borders. The Zagros system consists of a complicated series of mainly parallel, somewhat curved ridges. The ridges nearest to the Tigris are quite low, but each subsequent ridge is higher than the one before it, and the whole eastern region of this country has been very aptly compared with a gigantic ladder, ascending somewhat steeply from the Mesopotamian plains to the mighty mountains on the Persian border and beyond it. This sloping region is wide at first, at the latitude of Mosul, but farther south-east it gradually narrows.

Within this great arch of mountains there lies enclosed an arid country, mostly undulating, but without any great mountains. The only two ridges of some interest to us are the Jebel Abd-el-Aziz and the Jebel Sinjar, the first in Northern Syria, the second crossing the Syrian-Iraqi border. Much farther south there are the plateau and the mountains of Hauran, but they do not concern our problem. Barring these ranges, the country has a general south-eastward incline, and the two great arteries, the Euphrates and Tigris flow through it.

Most of the level country is usually called desert, but this is something of a misnomer, since it represents only a seasonal desert, during the summer drought, while the winter and spring rains transform most of it into more or less acceptable pastures, with a short but fairly dense cover of ephemeral grasses which are soon burnt by the sun. It is only on the lower alluvial plains of the Tigris and Euphrates that the true desert is met with, but again the soil there is highly fertile, if given artificial irrigation. If we move north of the Syrian-Turkish boundary, or north-east from the Tigris into the Kurdistan, the "desert" soon gives way to grassy steppes, which become more and more fertile with the altitude. In Kurdistan, at an altitude of about a 1,000 m. scrubby oaks are encountered, which form park-like open forests higher up, but the higher peaks of the mountains within the Iraq borders are bare and represent montane semi-deserts, with scattered spiny dwarf shrubs (*Acantholimon*, *Astragalus*, etc.), typical of the dry uplands of Iran and Armenia.

Invasion Area and Reservations of the Moroccan Locust.

It was obviously impossible, within the short time at my disposal, to investigate the whole country briefly described above, and I had to be content with becoming



acquainted with those parts of it which appeared to be most important from the point of view of the locust problem.

The approximate limits of the area subject to invasions by swarms of the Moroccan locust are shown on the map (fig. 1). It will be seen that the swarms may occasionally spread both to the alluvial desert lowlands and to the higher montane regions, but the history of previous invasions shows that the locust is unable to propagate successfully in such extreme areas, though the actual limiting factors remain unknown.

However, it is not the area liable to invasions during exceptionally great outbreaks which presents interest for us. From the point of view of developing a consistent anti-locust policy, it is much more important to know the *reservations*, or the areas where the outbreaks can originate. Indications as to the location of reservations can be obtained from the yearly maps of oviposition places, but unfortunately sufficient attention has not been paid to this side of the work by the local anti-locust organisations, and the maps prepared by them cannot be considered suitable for the purpose. In view of this, I decided to visit as many as possible of the places where the hatching of locusts was observed during the spring of 1932, or where locusts of the new generation were actually laying eggs during my trip. It was hoped to supplement these personal observations by inquiries as to the disposition of egg-laying grounds in previous years, in order to form a general idea of the natural conditions of the reservations. This plan was followed with considerable success and a series of breeding-places in Iraq, starting from Khanaqin and through the Kirkuk, Arbil and Mosul liwas, were visited and studied. The journey was then continued into Northern Syria, but the adjoining southern vilayets of Turkey remained outside the area investigated.

It will be realised that this rapid tour could not aim at the actual survey of reservations, but only at the elucidation of the most obvious natural conditions common to them all. Accordingly, I will not present a list of the reservations as found by me, but will discuss only such of them as appear to me most typical. Their approximate location is shown on the map (fig. 1).

The relation of reservations to the physiographical features of the country is quite obvious from the first glance at the map. The reservations are to be found in a relatively narrow belt on the lower slopes of the bordering mountain systems, at an altitude from 200–400 metres above sea-level. Thus, a considerable difference is observed from the reservations of the Moroccan locust in Western Anatolia, where they have been found at an average altitude of 800 metres (Uvarov, 1932). The probable reasons for this difference will be discussed later.

Vegetation in Reservations.

A serious handicap to my locust survey in Iraq and Syria was the almost complete absence of comprehensive botanico-geographical works on that area. Practically the only paper containing some information of the necessary kind is that by Handel-Mazzetti (1914), but it gives only rough and very generalised outlines of the main plant communities for some parts of our area. A botanico-geographical map of the area is, of course, non-existent. The following considerations are, therefore, based almost exclusively on my personal observations and must be regarded as purely preliminary in character.

Leaving aside the alluvial plains of Mesopotamia, the next altitudinal zone appears to represent mostly a semi-desert with *Artemisia herba-alba* as the landscape plant. In places, apparently where the soil is deeper, or perhaps more fertile, vast areas are covered by low leguminous shrubs, *Prosopis stephaniana*. Still another variety of the semi-desert is characterised by the presence of scattered creeping bushes of capers, *Capparis* sp. All these types of vegetation, and probably several more of their varieties, can be regarded as definitely unsuitable for locust breeding. From the



Fig. 1. General view of gravelly hills south of Kirkuk, a typical locust reservation area.



Fig. 2. Typical egg-laying place on the top of a hill-range west of Mosul.

Habitats of the Moroccan locust.



point of view of plants that may be called indicators of locust reservations, I would particularly emphasise the importance of *Prosopis stephaniana* and *Artemisia herba-alba* as definite negative indicators. It was in a single instance only that some scattered and dwarfed individuals of these two plants were found by me at a place which constituted a locust reservation (at Chekirge Ziarat, near Tauk, S.E. of Kirkuk).

An important plant association is a steppe-like vegetation of short tufty grasses on hard soil densely covered by pebbles. No detailed studies of this type have been made (since most of the plants were dried up), but the vegetation appeared to consist mainly of *Stipa tortilis*, *Carex stenophylla*, a small *Poa* sp. and similar plants forming an almost closed, but very short, cover. Again, in no case were egg-deposits found under such conditions, although they may be, and actually have been, encountered in their immediate vicinity. A typical case of this kind was observed, for instance, in the reservations some miles N.E. of Khanaqin. Here the lowest gentle slopes of rolling hills are densely covered with short yellow grasses, mostly *Stipa tortilis* with occasional scattered bushes of *Zizyphus nummularia*; other plants, also growing singly, were *Convolvulus reticulatus*, *Phlomis bruguieri*, a *Carduus*-like composite, etc. On this general pale-yellow background there stand out very strikingly more or less rounded patches on which the grasses practically disappear, or are represented only by isolated tufts, and here the egg-deposits are usually concentrated.

Other egg-deposits in the same locality were also invariably found just beyond, that is above, the short grass steppe, usually on the upper slopes of smaller hillocks. The soil where these deposits are, is always very hard and pebbly, up to 30-50 per cent. of the surface being covered by small rounded pebbles. The plants found in such spots never form a cover, but stand far apart from each other, the more common ones being *Convolvulus oxyphyllus*, *C. reticulatus*, *Teucrium polium*, *Heliotropium europaeum*, *Oliviera orientalis*, *Euphorbia lanata*, *Echinops* sp., and *Stipa tortilis*.

The prevailing vegetational types of the next altitudinal zone remain unfortunately little known to me, mainly because that zone includes very fertile areas and receives a sufficient amount of rainfall for regular cultivation of grain crops. As a consequence, practically all areas which can be ploughed are, or have been, under cultivation, and their natural vegetation has been destroyed. Such are the vast plains of the Kirkuk and Arbil liwas enclosed between low chains of hills. At the same time, it is in the immediate vicinity of these plains that some of the most important locust reservations are found. Thus, in the Kirkuk plain apparently the only suitable places for locust breeding are on the slopes of low hills bordering that plain from the south (Plate xii, fig. 1). Lower slopes of the hills, bordering on the cultivated land, bear a rather rich and varied flora. This includes such plants as *Salvia palaestina*, *Onosma aleppicum*, *Thymus syriacus*, *Delphinium rugulosum*, etc., which may be regarded as properly representing the vegetation of the rich steppes of the Kurdistan valleys. Higher up the slopes, the soil becomes very hard, and up to 80 per cent. of the surface is covered with pebbles. There is no continuous plant cover, and the following plants are found singly and stand wide apart: *Teucrium polium*, *Convolvulus reticulatus*, *Anchusa strigosa*, *Erodium cicutarium*, *Hypericum crispum*, *Oliviera orientalis*, *Euphorbia lanata*, *Pimpinella barbata*, *Gundelia tournefortii*, *Paronychia curdica*, *Passerina salsa*, and tufts of *Pennisetum orientale*; most of these plants are small and stunted.

In the Arbil plain the main reservations must be looked for in the similar low chain of Zirga Zarow hills, bordering the plain on the south. The location of egg-laying places there is almost exactly the same as in the Kirkuk hills, and the list of plants is identical. It is interesting to note that in the Arbil plain some egg-deposits were found on the plain itself, N.W. from Arbil, but again on somewhat raised and very pebbly ground, bearing most, but not all, of the above-named plants.

Farther to the north-west, in the Mosul liwa, the general conditions are somewhat modified. The steppes on the right, *i.e.* western, side of the Tigris are mainly on soils rich in gypsum. They are cultivated to a considerable extent, or used for grazing, and there was, at the time of my visit, very little vegetation left to enable me to form a definite idea of its general character. In any case, it was quite plain from what I learned about the usual egg-laying places and observed myself, that the locust reservations should be looked for only in some ranges of hills stretching from Mosul westwards, towards the Jebel Sinjar range.

On both sides of the Jebel Sinjar there stretch great undulating plains united under the name Jezireh and usually described as desert. In fact, they are not deserts, either in their soils, or in the vegetation. The Northern Jezireh, which I crossed in several directions, is characterised mainly by rather soft soils devoid of stones and bearing *Prosopis stephaniana*; in other places vast areas are overgrown by *Vinca herbacea*; in others again there are scattered numerous tufts of *Asphodelus* sp. A typical feature of the Jezireh is the presence of round hillocks, like large tumuli, called "tel." They rise only some 30-50 feet above the general level of the plain, but usually stand on a gently rising ground. The soil of the "tel" and of its base is always much harder than that of the plain and the vegetative cover is also distinct, consisting usually of scattered tufts of short grasses (apparently *Poa* sp., etc.). These raised foundations of "tels" appear to provide fairly usual breeding-places for the Moroccan locust, but I am not prepared to say that they should be regarded as probable reservations. Indeed, it appears that these "tels" are often selected for egg-laying for the simple reason that they are the only "islands" with sufficiently hard and compact soil in the midst of vast areas with soft soils avoided by the locust, and the eggs are laid there only by invading swarms.

The conditions in the Southern Jezireh, that is to the south of Jebel Sinjar, have not been studied by me in detail, but I have crossed the northernmost area of it, from Balad Sinjar, through Tel Afar, to Mosul. That area is characterised by the prevailing gypsum soils, which are not favoured by locusts for egg-laying, and I am inclined to think that breeding in the Southern Jezireh occurs only during outbreaks, and the existence of reservations there appears scarcely probable.

The Jezireh steppe, as it should be called, is continued westwards beyond the Iraq-Syrian frontier. Indeed, there is little marked change in the type of country when the frontier is crossed, except that there appears to be more cultivation in the Syrian Jezireh, than in the corresponding zone of the Iraq. The zone of Syrian Jezireh from the Turco-Syrian boundary to about 40-50 kilometres southwards is practically all under grain crops, or has been cultivated recently. It is only some small areas on steep slopes and the broad foundations of "tels" with hard soil that remain uncultivated, and here egg-laying takes place with considerable regularity. Judging from the evidence of local officials, some of such areas (for example Ker Hassar, Kherbet Topu, etc.) must be definitely regarded as locust reservations. As regards their origin, I am inclined to think that such reservations must be considered as secondary. They may have originated as a direct result of the extensive cultivation of the whole region, so that locusts were forcibly concentrated in the few remaining unploughed spots with sufficiently hard soils to meet their requirements. There is no need to stress the fact that these secondary reservations, surrounded as they are by vast cultivated areas, present an exceptionally great danger to the rich grain producing areas of Syria, and their thorough survey is greatly to be desired.

How far west this zone of the supposed secondary reservations extends, I am unable to say, since I had no chance to study the whole of it. However, the history of locust invasions in Syria suggests that the Aleppo province should be already regarded as a pure invasion area, and probably contains no reservations, the reason being climatic, as will be seen later.

The upper limit of the reservation zone in Iraq coincides fairly closely with the 500 m. contour line. Above that line there is a perceptible change in the vegetation,

which there may be called a rich steppe, with a closed cover of tall grasses and a great variety of other plants, particularly in the valleys between individual ridges. The slopes of hills bear, of course, less dense cover, but they are also steppe-like in character and their vegetation, if shorter, is continuous. There is little reason, therefore, to expect any locust reservations in these higher zones, and the history shows that they may only serve for temporary breeding. It would be advisable, however, to make a closer study of some areas of this Kurdistan zone, since in places hill slopes are sufficiently stony and bare to justify a suspicion of the existence of reservations. Such is, for instance, the case of the eastern extremity of the rich valley of the river Tanjero and its tributaries, in the vicinity of Halabja.

An important problem is offered by the southern vilayets of the Turkish Republic, adjoining immediately the Northern Jezireh of Syria. It will be seen from the map (fig. 1) that most of the area of these vilayets is above the 500 m. contour line, but on the other hand there is a possibility that reservations there extend to a higher altitude, for the climatic conditions are not the same as at a corresponding altitude in Iraq. Since, however, I had no chance of visiting these areas personally, and the existing maps of previous outbreaks do not appear to provide clear evidence against the existence of reservations in them, it would be best to leave Southern Turkey for future study.

This brief survey of the known and probable reservation areas shows that they occupy only a very narrow zone of the country. This zone begins somewhere south-eastwards of Khanaqin, probably near Mandali and in the adjoining Persian territory, and stretches like a curved ribbon, some 50-60 kilometres wide, through Kifri, Kirkuk and Arbil to Mosul. In the north-west it becomes broader and turns westward into Syrian, and perhaps Turkish, territory. Even within this restricted zone, locust reservations do not occur everywhere, but only on slopes of some low hill-ranges with hard pebbly soils and scanty, but peculiar, vegetation. There is little doubt that further ecological studies, executed preferably by an entomologist and botanist working together, will permit a definite idea of the vegetation typical for reservations to be formed, so that the probable reservations could be located by studying the vegetation of a particular place.

It must be realised that the connection between locust breeding and the vegetation is indirect. Indeed, there is not the slightest reason to think that the selection of egg-laying places by the Moroccan locust has anything to do with the presence of certain food-plants. Some of the oviposition sites have been visited by me when the locusts were actually laying eggs, and they invariably congregated on the barest spots, carefully avoiding all vegetation. Therefore, my suggestion in the report on Western Anatolia (1932) that the grass *Cynodon dactylon* may serve to concentrate locust eggs by attracting females to feed on it, must be rejected. As a matter of fact, I have encountered in Northern Jezireh in 1932 some locust swarms, ready to oviposit, settling on the lower slopes of a ravine where *Cynodon dactylon* was abundant, but the locusts did not seem to pay any attention to the grass and tended to concentrate on the higher and barer slopes.

Climate in the Reservation Zone.

Climatic regions of the area under study have never been defined except in a very general way, because until recently there existed therein only a few meteorological stations and these mainly beyond the reservation zone. The existing meteorological data for that zone are far from complete and do not cover any considerable period of time. Even these scanty data, however, permit some interesting conclusions to be drawn.

Annual isohyets (Normand ; see map) follow generally a course roughly parallel to the great arch of mountains bordering the area on three sides. It will be seen that the zone of locust reservations lies in the vicinity of the isohyet 375 mm. Indeed,

the actual average amount of annual precipitation for the three stations in the reservations zone (Kirkuk, Mosul and Urfa) was found to be 392.8 mm. This figure is somewhat lower than in the case of the Western Anatolian reservations, where it is 488 mm., but we shall see later that this difference is of very little significance.

Unfortunately, there are no recording stations in Kurdistan higher than Kirkuk, and it is, therefore, impossible to define the amount of precipitation which prevents the extension of the reservation zone into the hills. On the other hand, the 250 mm. isohyet coincides fairly closely with the extreme southern limit of locust invasions. In the west, the invasions are obviously limited by a zone of more abundant precipitation adjoining the Lebanon and Anti-Lebanon ranges. This zone, marked by the 500 mm. isohyet extends somewhat east of Aleppo, and to its influence must be due the absence of reservations from the more western areas of Northern Syria.

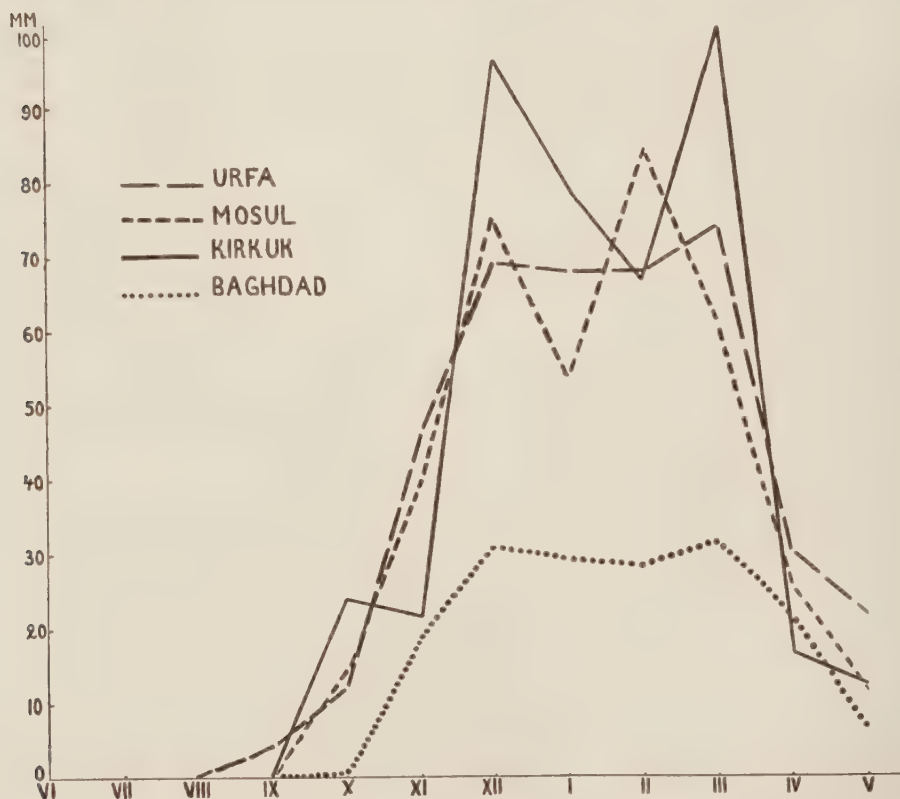


Fig. 2. Curves of monthly precipitation in the reservation zone (Kirkuk, Mosul, Urfa) and in the Mesopotamian plains (Baghdad).

The seasonal distribution of rainfall in the reservation zone is of particular interest. It will be seen from fig. 2 that the summer months (June, July and August) are entirely rainless, and it is only in December that abundant rainfall occurs; this continues until April, when the curve suddenly drops. The average amount of rain falling in the reservation zone during the months of December, January and February is 220.6 mm. The corresponding amount for the reservation zone in Western Anatolia (*l.c.*) is 190 mm., but this difference is of little importance, since in Western Anatolia there is no three months' drought and 110 mm. of rain falls in October and November, as against 52.3 mm. in the area now studied. Therefore, the slight

excess of winter rainfall in our area is fully balanced by the lesser amount received in the earlier months. Indeed, the total amount of rain falling between June and March (*i.e.*, during the egg-stage) is even less in our present area than in Western Anatolia, namely 274.2 mm. as against 355 mm. Thus, both areas have a very similar precipitation regime, which can therefore be considered as favourable for reservations.

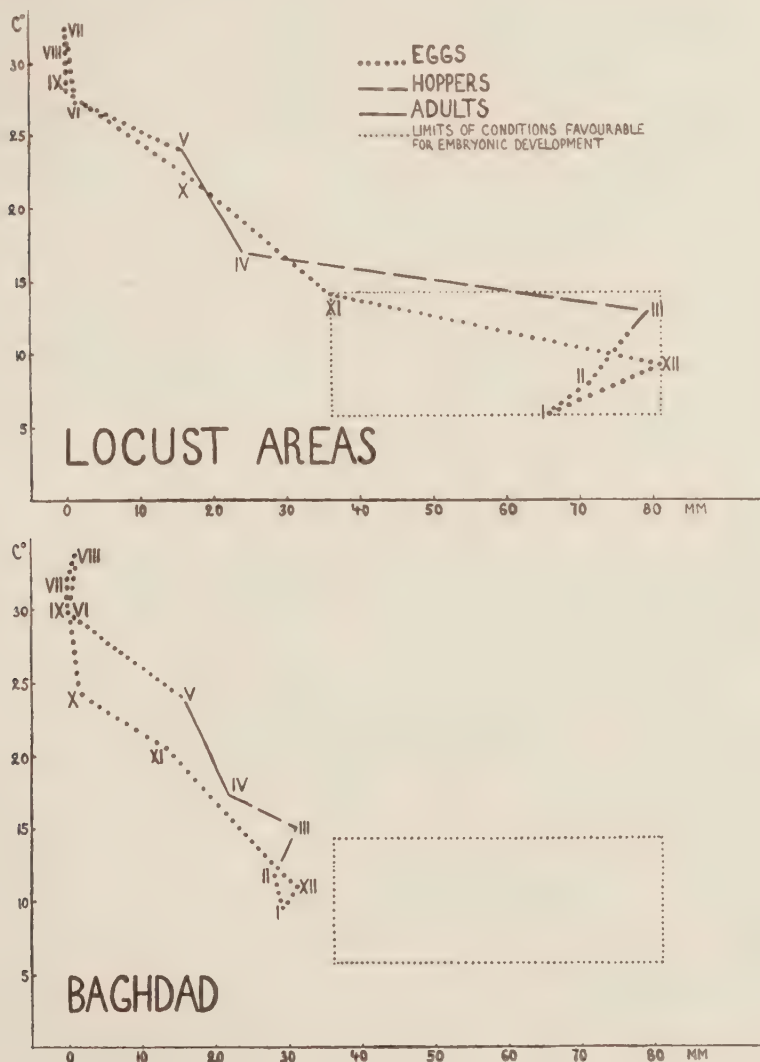


Fig. 3. Bioclimatographs for locust areas (top) and the Mesopotamian plains (bottom).

It is of interest to compare the climatic conditions in reservations with those at the extreme southern limit of the invasion area. Fig. 2 shows that the total amount of rain falling in Baghdad is very small (only 170 mm.), and the moisture is clearly deficient even in winter. A comparison of bioclimatographs (Uvarov, 1932) for locust areas and Baghdad (fig. 3) demonstrates still better the unsuitability of the

latter locality for locust breeding. Indeed, the square of the conditions (temperature and humidity) during the months when embryonic development occurs in reservations falls entirely outside the climatograph for Baghdad. In other words, it is obvious that the Baghdad conditions are wholly unsuitable for the development of eggs, though in certain exceptional years partial hatching may be possible.

Control of the Moroccan Locust on an Ecological Basis.

The necessity of ecological studies on the Moroccan locust, with a practical view of developing a comprehensive control policy, was urged by the present writer some years ago (Uvarov, 1928), mainly on theoretical grounds. Since then, field studies in Western Anatolia and in the Iraq-Syrian area have provided sufficient proof that reservations from which locust outbreaks start and spread over wide regions are not numerous, and are well defined. Indeed, in both cases, the reservations proved to be concentrated within strictly defined geographical, vegetational and climatic zones, and moreover very narrowly localised, representing often only small "islands" which can be identified by their soil and vegetation and accurately mapped out. There is no reason to suppose that in other areas subject to invasions by this locust the general conditions are essentially different from those found in the Middle East. Differences in detail must, of course, be expected. For example, in Hungary the Moroccan locust breeds, not in the original reservations, but in the areas which have been artificially made suitable for its breeding by the drainage of swampy areas (Jablonovsky, 1926). A closely parallel case is observed in the Northern Caucasus where breeding-grounds of the Moroccan locust have been created in the same way after the execution of big drainage schemes in the lower valley of the Kuban (Zacharov, 1932), while elsewhere in the same region secondary reservations were formed on overgrazed pastures near villages (Bei-Bienko, 1932).

However, these exceptional cases amount only to a difference in certain details of the ecological history of reservations, while the main point, which is the existence of definite and narrowly limited reservations representing the original sources of locust outbreaks, remains beyond doubt. The practical importance of this point cannot be denied, since it permits the present purely defensive anti-locust policy to be transformed into an efficient and more economical policy of the prevention of locust outbreaks. The following practical suggestions for studying reservations, as a preliminary for developing a preventive policy, are offered for the consideration of entomologists concerned with the Moroccan locust in other countries.

The first problem is that of the location of reservations. For this purpose it is necessary to institute a thorough annual survey of all oviposition sites. Maps of the areas infested by locust eggs are usually prepared in most countries, but they aim only at providing general information on the distribution of breeding-grounds and their area, this being necessary for the planning of the hopper campaign, arranging dumps of poison, etc. For our purpose, such rough maps are obviously of little use. What are wanted, are sketch-maps of each oviposition site, drawn on a large scale (at least, 1/50,000). There is no need for the maps to be very elaborate, but they must include the main surface features, such as hills, depressions, ravines, the prevailing type of soil and vegetation, etc., so that the place can be easily found in nature and its general character judged from the map. Maps of this kind can be prepared without the aid of instruments by anyone who has received an elementary instruction in map-making. The best arrangement would be to train all locust officers engaged in surveying egg-deposits in the preparation of sketch-maps. As an alternative, it can be suggested that locust officers should mark down the oviposition sites in nature, and a topographer be then sent round all the infested areas to prepare simple sketch-maps of each site.

If this plan is adopted, a valuable series of maps will be accumulated in a few years. This series would show at once which places are always chosen by locusts for egg-laying, and which serve for their breeding in exceptional cases only. It must be

realised that it would be particularly important to have exact records of the sites used for oviposition in the years when locusts are at their minimum. It is, unfortunately, a fact that during the minimum periods there is usually a tendency to neglect all work on locusts, while actually that is the best time for developing a preventive policy.

Side by side with the topographical work, which should assume a routine character, it is necessary to organise ecological studies of reservations, in order to discover the actual conditions causing locusts to select for oviposition certain spots in preference to others. This knowledge is important not only from the scientific point of view, but would provide a basis for attempts to alter the conditions in the breeding areas so as to make them unfavourable for oviposition in future.

Ecological survey would be best organised to cover a whole natural region, and its limitation by political or administrative boundaries may make it difficult for the ecologist to arrive at sufficiently well founded conclusions. From this point of view, a thorough ecological survey, extended over 2-3 years should be carried out in the whole Turco-Iraqo-Syrian area, including Western Persia as well, though local surveys would also be of considerable value for the particular country. Similarly in North-West Africa, it would be better to organise an ecological survey of the whole area of the "Hautes Plateaux" of the Atlas Mountains within the limits of Algeria and Morocco, rather than in each of these countries separately.

As regards the personnel required for the ecological surveys, it should include an entomologist and a botanist, both with an ecological turn of mind and a knowledge of field ecological methods. The entomologist should also possess a knowledge of the principles of climatology and of the necessary field technique. It is scarcely necessary to point out that the entomologist should have no administrative duties connected with locust control, since otherwise he would be fully occupied just when he ought to be free for his investigations.

The outcome of the topographical and the ecological work would be a map showing the distribution of locust reservations and a knowledge of the conditions of surface, soil, vegetation, microclimate, etc., which make reservations suitable for the production of the swarming phase. It is not difficult to see how this information can be utilised in practice.

An exact map of reservations would enable the anti-locust organisation in the country to arrange for keeping the reservations under strict supervision, so that the first attempts of solitary locusts to segregate can be suppressed at once by the ordinary control methods. In practice, this would mean a thorough inspection of all mapped reservation and suspicious sites immediately before and during the oviposition period.

Further, a knowledge of the conditions favourable for swarming may lead in many cases to a direct application of certain methods intended to oppose these conditions. In other words, it may often be possible to alter the conditions in reservations in such a way that breeding on an extensive scale would become impossible. For example, in the Northern Jezireh, particularly within the Syrian limits, locust reservations are located mainly round "tels" (see page 412), where hard soils prevail. There is scarcely any doubt that a single ploughing of these spots would render them unacceptable to locusts for egg-laying, at least for a couple of years to follow. Again, the main reason for the production of secondary reservations in Northern Caucasus and probably in some other countries is overgrazing, resulting in bare patches with hard soil, eminently suitable for the Moroccan locust. Obviously, a judicious management of grazing in such areas would lead to a restoration of the normal vegetative cover and to the virtual disappearance of locust reservations.

There is scarcely any need to dwell on the advantages of the suggested preventive policy as compared with the purely defensive measures now practised in all countries infested with the Moroccan locust. The cost of defensive campaigns is known to be very high, and the campaigns have to be repeated year after year, since no ultimate

success can be reached in the invasion areas. The non-recurrent expenses connected with an ecological and topographical survey of reservations are very small, and the cost of running an efficient permanent organisation for the supervision of reservations and the prevention of locust breeding in them would also constitute only a fraction of the sum required for a single defensive campaign.

There is, indeed, no justification for continuing the wasteful policy of controlling the Moroccan locust on a defensive basis, and anti-locust organisations in the respective countries would be well advised to concentrate on the study and control of reservations. Should conservative views be too strong for a complete reorganisation, it is always possible to continue the old defensive policy and at the same time to begin studying reservations, with a view to a gradual change in the anti-locust policy.

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PRELIMINARY EXPERIMENTS ON THE ANNUAL CYCLE OF THE RED LOCUST (*NOMADACRIS SEPTEMFASCIATA*, SERV.).

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Imperial Institute of Entomology.

Egg-pods of the Red Locust (*Nomadacris septemfasciata*, Serv.) deposited on the 17th January 1933 at Mazabuka, Northern Rhodesia, were kindly sent by air-mail to the Imperial Institute of Entomology by Mr. W. Allan. On their arrival 14 days later, the eggs were found to be perfectly healthy, apart from some having been damaged by pressure. Entire egg-pods, with the surrounding soil, were placed in wet sand in flower-pots and put in a glass cage. The temperature in the cage was kept at 100°F. during the day and 80°F. during the night, but that of the sand was probably somewhat lower. Hoppers began to hatch on the 2nd of March and were kept at the same temperatures, with a humidity as near the saturation point as could be maintained. The first adult appeared on 8th April, and the majority of hoppers became adult by the 18th of April, six and a half weeks after hatching. Owing mainly to cannibalistic habits of the hoppers, only about 40 adults were obtained.

It was obviously impossible to plan any serious experiments with such a small number of locusts available, without risking the loss of the entire stock, and it was decided to use them for a preliminary experimental test of the conditions necessary for the sexual maturation. This particular problem is of great practical importance and no data bearing on it were available. It can be considered as definitely established by direct observations in the field and by a study of monthly reports received at the Institute, that the normal life-cycle of the Red Locust in its breeding-areas south of the Equator comprises a single generation in a year. Eggs are laid and hoppers emerge during the rainy season, which occurs there during the northern winter, between November and March. Adults appear early in the dry season and do not reproduce again until the next rainy season, passing about 7-9 months apparently without maturing sexually. The question now arises whether this long imaginal diapause is due to an inherited rhythm, or is indirectly dependent on the climatic conditions, being caused by the low humidity and low temperatures during the dry period. The question is not of academic interest only, since adult swarms of the Red Locust are known to undertake very long migrations, spreading from their breeding-areas mainly to the west and to the north. The available records, though they are incomplete, suggest that this movement of swarms is connected with the seasonal retreat of the rains in the same general directions. The swarms may reach in their migrations deep into the Belgian Congo (apparently to the limit of the great forest) in the west, and to Uganda in the north. As far as is known, no breeding occurs there, and the same swarms return again to the east and south later in the year, with the advancing rains.

These extensive migrations of the Red Locust must bring at least some swarms into areas with a local climate favourable for breeding. Should the annual cycle be a fixed one, this would make no difference, but should it be influenced by climatic conditions, then we must be prepared for the possibility of the migrating swarms settling to breed in areas previously free from infestation.

In order to throw some light on this problem, the locusts were divided into two lots. One of these was placed in a glass cage (accumulator jar 38 by 38 by 54 cm.) covered with a lid of perforated zinc, with a little dry sand at the bottom, and kept at a temperature of 100°F. during the day and 80°F. during the night. The sand was never moistened and the relative air humidity in the cage averaged 30-40%.

Another cage was kept at the same temperature, but the lid was covered with thick cellophane to stop the evaporation. The air humidity in this "wet" cage averaged 70-90%, sometimes reaching the saturation point.

The development of locusts in the wet cage went as follows: On the 28th April, about ten days after the final moult, the hind wings assumed a pink colour. On 22nd May some eggs were found scattered on the sand; they were placed in wet sand, but failed to hatch. On 23rd May one pair was observed copulating, and on the 1st June an egg-pod was laid in the sand. Copulation and egg-laying continued intermittently until the time of writing (third week in July), though the locusts began dying one by one already in the second half of June. On 13th July, the first hoppers hatched, six weeks after the first eggs were laid, and the hatching is continuing steadily at the time of writing.

The locusts in the "dry" cage developed in the same way, with but little difference. The first case of copulation occurred on the 20th May, and an egg-pod was found on the 19th June, though it is possible that some eggs were laid earlier, since hoppers began to hatch on the 18th July.

While the experiments just described were admittedly of a preliminary character, their results are quite conclusive as regards the main problem. They supply a definite proof that the usual annual cycle of the Red Locust is dependent on the actual climate cycle and is not a fixed hereditary character. In practice, this means that a second generation can be produced in the more northern and western areas reached by swarms, at least in some areas with an exceptionally wet and hot climate. Particular attention should be paid, therefore, to the behaviour of invading swarms, especially in the interior of the Belgian Congo, and along the valleys of the great lakes, which may conceivably possess the necessary climatic conditions at the appropriate season.

The present note is intended merely to make known these facts and suggestions, and it is not proposed to discuss the experiments in more detail. While the results obtained so far appear to suggest that a high temperature is more important for the sexual maturation of the Red Locust than a high humidity, they cannot be considered conclusive in this respect. The fact that the maturation of locusts in the dry cage was retarded only by a few days as compared with those in the wet cage may be due to the influence of water in the food, since both lots were fed on fresh green grass. More detailed and exact experiments will be devised in order to study the effects of temperature and humidity separately and in various combinations.

THE BIOLOGY AND CONTROL OF *ASTEROLECANIUM COFFEAE*, NEWST., THE FRINGED SCALE OF COFFEE, IN KENYA COLONY.

By H. C. JAMES,

Ph.D. (Cantab.), Ph.D. (Vict.), B.Sc. (Agric. Edin.).

(PLATE XIII.)

1. Introduction.

East Africa appears to be the only part of the world where a species of *Asterolecanium* has become an important pest of coffee. *Asterolecanium coffeae* occurs in Kenya, Tanganyika, and Uganda, and in the latter territory another species of the genus, *A. hancocki*, Laing,¹ has also been collected from coffee, but although its "test" is quite distinctive, it was not observed in Kenya during the course of this investigation.

A. coffeae was described by Newstead in 1911 and his description⁴ was evidently based on specimens from old wood, since the species is stated not to make depressions in the bark. It is only on the young green wood of the host that the characteristic pit-like depressions of this scale are produced. The only amendment required to the original description of the species has been made by Laing,¹ who points out that the filaments of the "test" are not golden yellow as described by Newstead (from spirit material only) but have a very distinct pink colour.

A. coffeae was first collected in Kenya by G. W. Evans on coffee plants seven miles north-east of Nairobi in 1912, and in 1913 C. C. Gowdey collected it from the same host in Uganda. It became troublesome in Kenya after the war, when coffee began to be extensively cultivated in the lower, drier and hotter areas below 5,000 ft. It occurs, however, in every coffee district of the Colony.

2. Nature of Damage by *Asterolecanium*.

Heavy infestations of *A. coffeae* not only destroy the crop of the current season but so warp and distort the crop-bearing wood as seriously to lower the future reproductive power of the trees. In fact there is no known scale pest of coffee in the Colony which produces such deleterious after-effects. Although in the case of bad attacks the crevices of the older bark contain a mass of scales in all stages of development, which must have a very devitalising effect on the host, it is on the young wood of the primaries and secondaries where damage of the most serious kind is inflicted. On a green twig the favourite position of *A. coffeae* is at the node (Plate xiii, fig. 3) near the base of the leaf-petiole, from which it can tap conveniently the conducting tissues leading to and from the leaf. Leaves which are thus deprived of their sap speedily turn black and remain on the trees, drooping in a characteristic fashion.

The green stems become sharply warped at the points where the scales are feeding, and it is noticeable that the "twist" is always towards the side where the pest is situated. The internodes beyond the points of attack are elongated and the production of long whip-like branches is a characteristic after-effect. Although occasionally found on the berries, and more rarely on the leaves, they have no special partiality for these positions, and their presence in such situations is usually indicative of a bad attack.

3. Life-history of *Asterolecanium*.

Asterolecanium coffeae is strictly oviparous and the ova pass through a period of incubation within the "test." When the female dies her shrivelling body is pressed into the anterior region of the "test" by the accumulation of ova which fill the

cavity thus formed. The eggs are yellow ovoid bodies about 0.30 mm. long, and after eclosion the larvae emerge from the "test" through an opening at its posterior extremity and seek suitable feeding positions.

The fecundity of *A. coffeae* is low compared with the other important coffee-infesting COCCIDAE of Kenya, and the writer has never counted more than 70 eggs beneath a fully developed test, the average number being about 50.

The male is extremely rare, and the fertilisation of the female must be a very infrequent occurrence.

Infestations of *A. coffeae* are usually most severe and apparent towards the close of each of the two dry periods of the year, which, in the areas most affected, normally occur during the months of March and October. Although each rainy season brings about some reduction in the numbers of the pest, infestations on neglected plantations become progressively worse during each succeeding dry season.

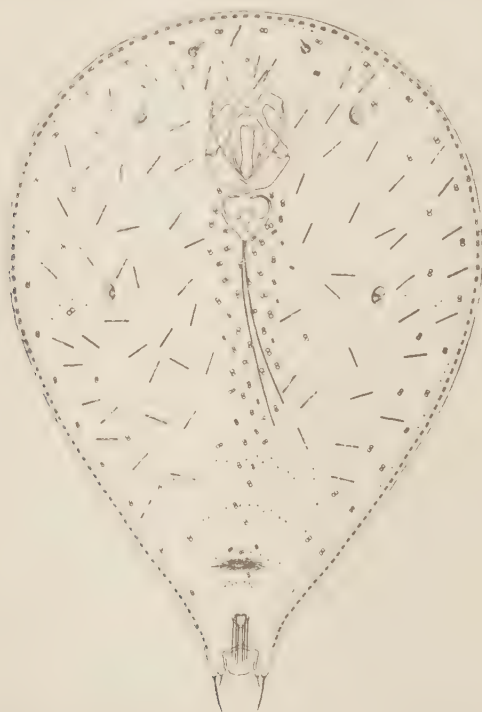


Fig. 1. *Asterolecanium coffeae*, Newst.: adult female (dorsal view) with the test dissolved off. $\times 60$.

The heavy flow of sap induced by the "rains" results in great reproductive activity among the surviving scales, and there is a noticeable migration of larvae from the older parts of the tree to the rapidly developing shoots. Once a first instar form has begun to feed, it seldom changes its position, and the characteristic filaments which are produced from the 8-shaped gland-pores, or octacerores, soon become observable.

First instar forms have been observed to feed for as many as twelve and as few as seven days before the first ecdysis occurred. The filaments grown during the first stadium are then cast and a "test" is developed which has pronounced marginal and mesial fringes of filaments (fig. 2b). The duration of the second stadium has been observed to vary from 18 to 25 days, and at the second ecdysis the "test" grown during the second stadium is cast along with its associated filaments.

Immediately after the final moult the insect resembles the egg-laying female except in size, but the "test" which encloses it changes greatly in appearance during the pre-oviposition period. The adult "test" is plate-like at first with a very pronounced median ridge on which develops a dense crest of filaments, and a marginal fringe is grown at the same time. Later, the "test" becomes more convex dorsally, the median ridge disappears, and finally the mesial and most of the lateral filaments are lost (Pl. xiii, figs. 1, 2).

The adult female increases to nearly twice her original size before oviposition begins, and in view of the remarkable changes in the appearance of the "test" evidence of a third ecdysis was long sought for. However, continuous observation and many dissections showed that only two ecdyses occur in the development of the females.

Oviposition begins about 28 days after the final ecdysis, and the total length of the life-cycle of the female, reckoned from eclosion to the commencement of oviposition, varies from 60 to 70 days.

A. coffeae is not a honeydew-producing Coccid and is therefore not attractive to ants, which play no part in the intensification of outbreaks. *A. coffeae* does not possess a wide range of food-plants, and the writer has collected it only from loquats (*Photinia japonica*) and *Jacaranda* sp. in addition to coffee (*Coffea arabica*).

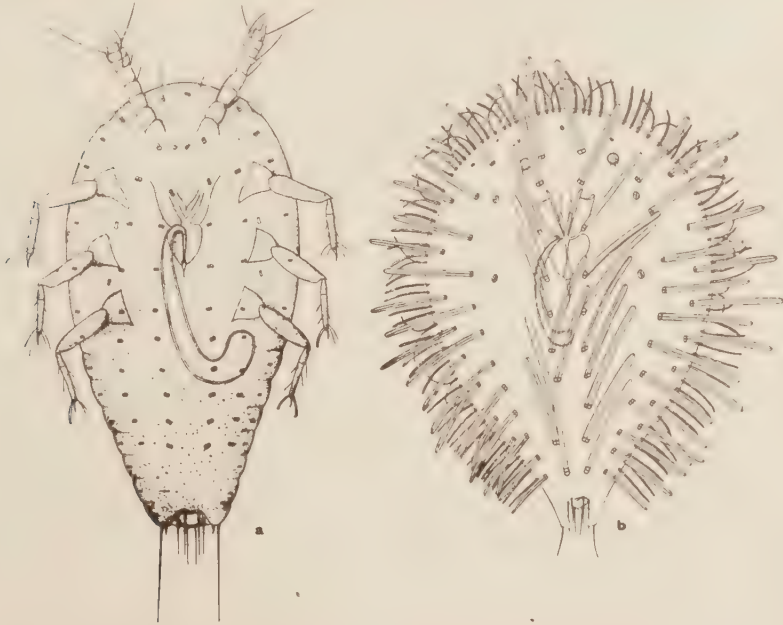


Fig. 2. *Asterolecanium coffeae*, Newst.: *a*, the first instar (dorsal view). The mouth-parts, legs and antennae are shown reflected through the body. $\times 150$. *b*, the second instar form of the female enclosed within its test (dorsal view). Mouth-parts and antennae reflected through. $\times 72.5$.

4. Description of the Immature and Adult Stages of the Female.

The first instar of the female measures from 0.30 to 0.40 mm. in length (fig. 2*a*) and is of the same colour as the eggs. It is approximately elongate oval and somewhat flattened dorso-ventrally.

The head is indistinguishably fused with the thorax, and only seven abdominal segments are clearly demarcated posteriorly. On the anterior margin are two

colourless eye-spots, which are very inconspicuous in living specimens. A pair of feebly capitate antennae are prominent features, and although their segmentation is sometimes obscure, eight joints can be distinguished in the majority of specimens.

Despite the fact that first instar forms possess six fully formed legs, they are incapable of such rapid movements as the corresponding stage of many Lecaniine scales, notably green scale (*Coccus viridis*, Green). At the posterior extremity there is a pair of small anal lobes, each bearing two setae, an outer long one and an inner very short one. The invagination between the lobes contains an anal ring, which is situated towards the dorsal aspect and is invariably armed with six setae.

The only structures of note on the derm are the 8-shaped gland-pores, or octacerores. In addition to a series of 28 pores round the margin there are two rows each consisting of ten pores in the median dorsal region, and between the median and marginal series on each side is another row of ten.

There is little increase in size during the first stadium, but the second instar varies in length from 0.48 mm. to 0.80 mm. This instar shows modifications appropriate to its sedentary mode of life, since the legs, eyes, and all traces of segmentation, have disappeared, and the antennae are reduced to two small stubs with three or four hairs on their apices.

The dorsal series of octacerores described in the first instar are still represented, but round the margin there has appeared a closely set series of smaller octacerores which are chiefly responsible for the production of the marginal fringe of filaments. Submarginally there is observable a series of circular uniporous pores, which stain deeply, and it may be fairly safely concluded that from these pores is exuded the thin sheet of wax which is interposed between this insect and its host from the second stadium onwards.

The second ecdysis occurs when the length of the insect measures about 0.80 mm., but the average length of a full-grown adult is about 1.50 mm. The principal observable differences distinguishing the adult female from the second instar are the breaking up of the paired and regular arrangement of the larval octacerores and the appearance of numerous smaller ones in the median dorsal region (fig. 1). Ventrally there is an additional series of uniporous pores which possess rather larger orifices than those on the margin and are arranged in four transverse bands in the posterior region of the abdomen. The genital opening lies between the two posterior bands and usually can be detected only in very mature females. There also occurs on the ventral aspect a tract of uniporous pores extending from each spiracle to the margin.

Opening on to the dorsal surface are numbers of rather elongated tubular glands. The only difficulty in accepting the conclusion of Green² that these glands secrete the homogeneous part of the "test" is that, although the latter appears to be structurally similar in the adult and immature stages, the glands are present only in the adult.

5. Parasites and Predators.

Only one species of parasite was secured, and this was identified by Dr. Ch. Ferrière, through the courtesy of the Director of the Imperial Institute of Entomology, as *Metaphycus lounsburyi*, How. There is no previous record of the latter infesting a species of *Asterolecanium*.

M. lounsburyi was described by Howard in 1898 from specimens bred from *Saissetia oleae*, Bern., collected at Cape Town, and was subsequently imported into California both from Cape Town and from New South Wales to assist in controlling *S. oleae* (Citrus Black Scale) in the citrus orchards.

The biology of *M. lounsburyi* has been investigated by Smith & Compere.⁵

Occasionally high incidences of *M. lounsburyi* occur in *A. coffeae* near the close of the dry season, but it can never be relied on to effect complete control of the pest in the areas most favourable to the latter, and probably the principal factor in reducing its effectiveness is a secondary parasite identified by Dr. Ferrière as *Perissopterus busckii*, How. (fig. 3). The latter has been described by Mercet³ as "either a parasite or hyperparasite of *Asterolecanium aureum*, Boissduval, in Porto Rico." Smith & Compere⁵ suspected *P. busckii* of being a hyperparasite of *S. oleae* through *M. lounsburyi* in California, but they did not regard their evidence as conclusive.

Several species of COCCINELLIDAE are suspected of preying on *A. coffeae*, but definite proof has only been obtained in the case of *Chilocorus angolensis*, Crotch.

Where infestations of the pest are heavy, this species of ladybird may frequently be seen resting apparently motionless for hours together among masses of scales, but it has never been detected in the act of breaking into the "tests" of mature individuals. It feeds mainly, if not entirely, on the mobile first instar forms as they issue from beneath the "tests" of the mother scales.

Exochomus nigromaculatus, Goeze, and *Chilocorus discoides*, Muls., are other species of ladybirds which are probably predators on *A. coffeae*, although they have not actually been observed in the act of feeding on the latter.

The control value of species of COCCINELLIDAE in relation to *A. coffeae* is chancy and of much less importance than in the case of *M. lounsburyi*.

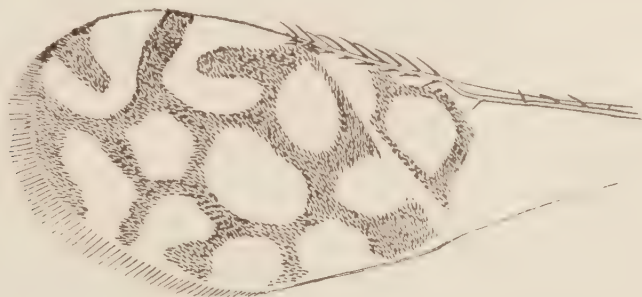


Fig. 3. The right forewing of *Perissopterus busckii*, How., a secondary parasite of *Asterolecanium coffeae*.

6. Control Measures.

Although *A. coffeae* develops comparatively slowly and has a lower reproductive capacity than most of the common coffee COCCIDAE of Kenya, the eradication of an infestation is a matter of the utmost difficulty, because the scales are not only embedded in small depressions formed in the green wood but are also protected by horny (ceravitreous) "tests" which resist the disintegrating action of five per cent. caustic potash at 15°C. for 24 hours.

Pruning of the most drastic character will not remedy the severe distortion of the crop-bearing wood, especially when this is accompanied by the debilitating effect of masses of scales on the old wood.

Only one course of action is really economical in the case of heavily infested plantations, and that involves the cutting back of the trees to about one foot above ground-level.

This operation is also known as "stumping" and should always be performed just before the trees are about to make new growth; but as a considerable number of trees in a badly infested area will be in a state of "dieback," stumping them in that condition may have to be accepted as the lesser of two evils.

The infested trees should be removed from the stumped area as soon as possible to avoid extensive re-infestation of the stumps, and the latter should be scrubbed (not sprayed) with Orthol K and then heavily whitewashed. Afterwards inspections of the new growth should be made at frequent intervals to ensure the early detection of re-infestation.

The expense and loss resulting from "stumping" makes it imperative that the control measures for *A. coffeae* should be largely of a preventive nature.

The hotter and drier districts between 4,000 and 5,000 ft. are peculiarly favourable for the pest, and in such localities a close supervision of the trees must be maintained and incipient outbreaks treated at once.

For light foliage infestations judicious pruning may be of value, and the infested twigs should be collected and burnt, but where the scales are present on the main stems spraying should always be resorted to. The spray recommended is Orthol K, which should be used at a strength not greater than 1 in 25 (in water) and not less than 1 in 23, and the application should be renewed not less than a fortnight and not more than six weeks after the initial one.

The second application of spray is always necessary to destroy the progeny from a number of eggs which always remain viable after the first application, owing to the protection they receive from their chorions and the "tests" of the mother scales.

The best time for spraying is near the end of each rainy season, because great reproductive activity is then occurring among the scales on the older bark of the trees and an abnormally large number of individuals are in the vulnerable mobile stage.

In cases where an infestation has been sufficiently heavy to necessitate severe pruning after spraying, due regard should be had to the condition of the trees in respect of "dieback," and pruning would sometimes be better postponed until later in the dry season when the sap is not moving so rapidly and the trees have recovered to some extent.

The fact that parasites and predators are rarely dominant controlling factors, and that Orthol K is more effective than sprays which were formerly used, enables greater freedom to be exercised in the selection of the time for spraying. Nevertheless in choosing a time for this operation it is well to keep in mind the fact that the incidence of parasitism is always highest towards the end of the dry season and that the pest is in its most vulnerable stage about the end of the rainy season.

Many observations have led to the conclusion that the physiological condition of the host which favours the presence of this pest occurs most frequently on soils lacking in humus, and consequently the reserve of organic matter in the soil should be built up by every available means.

7. Summary.

(1) *Asterolecanium coffeae* occurs in all the British East African Dependencies and has been the cause of much loss in certain low-lying coffee areas of Kenya. On the crop-bearing parts of the coffee tree (*Coffea arabica*) it inflicts injuries of an irreparable nature, and a heavy infestation is extremely difficult to eradicate.

(2) *A. coffeae* is oviparous, and after deposition the eggs pass through a period of incubation within the "test" of the mother. The fecundity of the female is low compared with that of the common Lecaniine scales and mealybugs which infest coffee in Kenya. The average number of eggs produced by a single female is about 50. The male is extremely rare and fertilisation of the female must be a very infrequent occurrence.

(3) The duration of development of the female from egg to egg varies between 60 and 70 days. The duration of the first stadium varies from 7 to 12 days, and that of the second stadium from 18 to 25 days. The pre-oviposition period is 28 days.

(4) The various stages of the female scale are described.

(5) Only one primary parasite of *A. coffeae* was obtained, namely, *Metaphycus lounsburyi*, How., and it is frequently abundant towards the close of the dry season, but its effectiveness is nearly always considerably reduced, by the high prevalence of a secondary parasite, *Perisopterus busckii*, How. A Coccinellid, *Chilocorus angolensis*, Crotch, preys upon the mobile first instar forms.

(6) *A. coffeae* is not a honeydew secreting Coccid and is entirely ignored by ants.

(7) *A. coffeae* occurs on loquats (*Photinia japonica*) and *Jacaranda* sp. in addition to coffee (*C. arabica*), and prefers the lower, drier and hotter coffee areas below 5,000 ft. There is a considerable amount of evidence to suggest that the physiological condition of the host which induces heavy attacks of *A. coffeae* is connected to some extent at least with a deficiency of humus in the soil.

(8) The procedure necessary to maintain control in plantations liable to severe attack is described. When an infestation is sufficiently severe to necessitate spraying, Orthol K should be applied at a strength not greater than 1 in 25 (in water) and the application should be renewed not less than a fortnight and not more than six weeks after the initial one.

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TAXONOMIC NOTES ON THE COFFEE MEALYBUGS OF KENYA COLONY.

By H. C. JAMES,

Ph.D. (Cantab.), Ph.D. (Vict.), B.Sc. (Agric. Edin.).

(PLATE XIII.)

The following species of mealybugs have been collected from *Coffea arabica* in Kenya Colony :—

Pseudococcus lilacinus, Ckll.

Pseudococcus citri, Risso.

Pseudococcus simulator, sp. n.

Pseudococcus virgatus, Ckll.

Pseudococcus perniciosus, Newst. & Willc.

Pseudococcus longispinus, Targ.

It is possible that additional species may be collected, especially from the coffee districts of Western Kenya, which are very distant from Nairobi, but undiscovered species, if they exist, can be little more than entomological rarities.

Identity of the Common Coffee Mealybug of Kenya.

The establishment beyond dispute of the identity of the commonest species of coffee mealybug is not only a matter of interest, but may become important, because the available evidence points to the conclusion that the species has been introduced into East Africa in comparatively recent times.

The writer has discussed at some length¹ the probable origin of the coffee mealybug outbreak which occurred in 1923, and it is sufficient to state here that it was at first very local in its incidence. Subsequently the pest spread gradually into contiguous areas and the present zone of infestation, although much larger than in the earlier years of the outbreak, still occupies only a relatively small area of the Colony. It is difficult to reconcile this mode of origin and spread with the assumption that the species of mealybug concerned is indigenous.

Pheidole punctulata, Mayr, the commonest and most assiduous attending ant, which greatly intensifies the damage that the mealybug is capable of causing, is a common Ethiopian species and existed in the present zone of infestation long before the mealybug was observed.

It should also be pointed out that proof of the existence of biological strains or races of the common mealybug, which were thought to have restricted host ranges on indigenous plants, has not been obtained.

When the first infestations of the common mealybug occurred they were not unnaturally attributed to *Pseudococcus citri*, Risso, because of the close similarity of the latter to *P. lilacinus* and to the fact that *citri* had been recorded a long time ago from coffee in the Colony. Later, when the common mealybug was identified as *P. lilacinus* the occurrence of *citri* on coffee (at least among the foliage) was doubted. However, further work has shown that *P. citri* also occurs on *Coffea arabica* in the highlands of Kenya and that in the zone of infestation of *P. lilacinus* its presence is masked by the much greater abundance of the latter.

The species of coffee mealybugs in Kenya which have been identified as *P. citri* and *P. lilacinus* have been reared under controlled conditions in the laboratory, and

the biological data obtained support the view that they are distinct species. For instance, *citri* is a much slower breeder (on *C. arabica* in Kenya) than *lilacinus*, and the duration of the egg-stage is considerably longer under the same set of conditions.

Pseudococcus lilacinus was first described by Cockerell from specimens collected from cultivated orange in the Philippine Islands, in 1904, the name *lilacinus* being derived from the blue-green pigment which forms in the body after boiling in caustic potash.

In 1920 Morrison³ re-examined Cockerell's type material of *lilacinus* and subsequently stated that although the species is quite closely related to the common citrus mealybug in many of its structural characters, it is viviparous and has much stouter legs and antennae.

Species of mealybugs to which the name *P. lilacinus* has since been applied have been recorded from Uganda, Kenya, Tanganyika, Jamaica, Java, Mysore, Straits Settlements and Ceylon, but whether these records refer to the same species in all cases is perhaps doubtful. The writer, however, has satisfied himself that the common coffee mealybug of Kenya also occurs in Uganda and Bukoba (Tanganyika).

Messrs. Green and Laing determined the common coffee mealybug of Kenya as *Pseudococcus lilacinus*, Ckll., but added the note that "the amount of variation in the development of the front legs is considerable." Mr. Morrison has compared preparations sent by the writer with type slides and with specimens from India, Ceylon and the Philippines which had been identified either as *lilacinus* or as *crotonis*, Green. He stated "I observe only two differences that seem to me to be at all tangible; first, the legs of your specimens apparently are not so stout as those of *lilacinus*; and second, the dorsal abdominal region of specimens of *lilacinus* apparently bear somewhat larger stouter setae (present in transverse segmentary arrangement) than does the corresponding area in your specimens. This may or may not be significant, and it is easily explainable if one assumes even a small range of variation in the species. The possibility, however, is not eliminated that your specimens instead of representing *lilacinus* is actually still another, although extraordinarily closely related, species in the *Pseudococcus citri* complex."

Now, in view of the fact that slight morphological differences are sometimes correlated with very considerable differences of habit (especially in the case of mealybugs) the best chance of arriving at an indubitable conclusion with regard to the identity of this species of mealybug would seem to reside in a comparison of biological data from the countries where it is alleged to occur.

Unfortunately the biology of *lilacinus* has not received attention in any part of the world except in Kenya, and all that exists for comparison is the statement by Morrison that *lilacinus* is viviparous or ovoviviparous.* With regard to this matter Morrison informed the writer (*in litt.*) that he had no personal experience in the field with *lilacinus* (or *crotonis*) and that his statement is based upon examination of adult females which showed within the body (after ordinary preparation treatment) numerous well developed larvae.

Now, fully matured females of the common coffee mealybug of Kenya almost invariably contain apparently fully formed larvae which are liberated from their egg-cases by the rupture of the latter during preparation for mounting, and it would seem that under the same environmental conditions the duration of the egg-stage (if any) would not be very different from that of Philippine specimens of *lilacinus*.

Under normal laboratory conditions (that is at temperatures between 20° and 30°C.) the coffee mealybug is invariably oviparous, and for some considerable time the writer was of the opinion that there was always a period of external incubation

*Mr. E. E. Green describing *Dactylopius crotonis* from Ceylon, which has since been synonymised with *P. lilacinus*, Ckll., stated that the species was ovoviviparous (J. Econ. Biol., vi, pt. 2, p. 35, 1911).

before eclosion. However, the relative scarcity of ova observed under actively breeding females, a very large number of which were being examined direct from the field for the collection of the larvae of their predators, convinced the writer that under conditions which quite commonly obtain in the coffee plantations a very large percentage of the progeny hatch either ovoviviparously or after a few minutes of external incubation.

There is another factor, apart from physical conditions, which may have some effect on the time of eclosion of the larvae and that is whether the progeny are from fertilised or unfertilised females. In experiments on parthenogenesis in this species (to be described in another paper) virgin females produced eggs which hatched in from 12 to 43 hours, but the former were reared in petri dishes in conditions which greatly slowed down the rate of their development, and no conclusion could safely be arrived at.

The effect of temperature on the duration of external incubation in the laboratory was most noticeable in the case of ova which experienced a sharp drop in temperature soon after oviposition.

For instance, ova laid between 4 p.m. and 6.30 p.m. and experiencing a minimum night temperature on successive nights of 11°C. and 15.5°C. hatched in from 23 to 73 hours, with a mean duration of 35.75 hours in the case of 307 ova from 13 females.

On the other hand, 47 ova laid between 8 and 10 a.m. and experiencing a maximum day temperature of 35°C. had all hatched before 2 p.m. on the same day. Ova maintained in the laboratory at an almost even temperature (varying only between 21°C. and 23°C.) hatched in from 1 to 43 hours in the case of 289 ova from 15 females, with an average duration of 15.47 hours. There are also two exceptional cases on record in which eclosion has only occurred 87 hours and 104 hours respectively after oviposition.

The relatively wide variation in the time of eclosion in the case of ova laid within an hour or two of each other and maintained under the same conditions can only be explained by variations in the stage of development reached by embryos at the time of oviposition.

Hence the conclusion would seem to be that alleged differences in the period of the external incubation of the ova are of no importance in finally determining the identity of the common mealybugs of Kenya, and that if it be true that the latter has a greater tendency to ovipositing than *P. lilacinus* in the Philippines, the fact is adequately explained by the different physical conditions prevailing in the two countries. Indeed it is quite conceivable that *P. lilacinus* may occur in situations where it is almost entirely oviparous and where the duration of the egg-stage (external) is considerable. In such circumstances the ovisac would be voluminous, as in the case of *P. citri*, since the apparently small ovisac of *lilacinus* is really due to its continual dispersal by the rapidly hatched progeny.

Thus whilst it appears probable that the common coffee mealybug of Kenya should be referred to *Pseudococcus lilacinus*, Ckll., there are certain morphological differences which may be insignificant, and it would behove an entomologist who became engaged in the task of introducing parasites of *P. lilacinus* into East Africa to give the taxonomic side of the question his closest attention.

Recognition Marks of *P. lilacinus* and *P. citri*.

In addition to the element of uncertainty which existed, and which may perhaps still be said to exist, with regard to the precise identity of the common coffee mealybug, there was also the difficulty, especially felt in the field, of separating it from the closely allied species *P. citri*. The latter, despite its wide distribution in the Colony (it occurs in every coffee district, whereas the range of *P. lilacinus* is still confined to the coffee areas contiguous to Nairobi), is of very minor economic significance, and beside the necessity of being able to distinguish it from the common mealybug for

experimental purposes, it is sometimes of importance to know whether it is this harmless species which has invaded a coffee plantation or whether the much more dangerous species, *P. lilacinus*, has to be coped with.

Elaborate descriptions and re-descriptions of both these well known species have been made, and it is not intended to add to their number. It is proposed here to point out those differences which the writer has found in practice to afford the most reliable means of separating them.

Perhaps the most reliable diagnostic character in the field is that the ovisac of *citri* is much larger than that of *lilacinus*. Probably, however, the latter secretes as much ovisac as *citri*, but this is not evident because it is being continually dispersed by the rapidly hatched progeny. The egg-stage of *citri* is considerably longer than that of *lilacinus* under the same conditions, and a large number of ova can generally be found in the voluminous ovisacs of actively breeding females, whereas in the case of *lilacinus* ova are seldom found in numbers, even when the females are breeding rapidly.

There are also differences in the waxy pattern of the dorsum, the most noticeable being that a median longitudinal groove which is present in both species is, as a rule, much deeper and better defined in *lilacinus* (Pl. xiii, figs. 4, 5). Moreover the wax of *lilacinus* is more commonly granular than that of *citri* and its intersegmental grooves are deeper and wider.

The body colour of young females of *citri* may be yellow, as in the case of *lilacinus*, but more frequently it is orange-brown. Body colour is a most unreliable means of differentiation, because the females of *lilacinus* as they grow older assume various shades of yellowish brown. The writer was unable to make use of the colour of the exudates of the dorsal ostioles for purposes of identification.

A much greater proportion of the males of *citri* make their cocoons in the foliage than those of *lilacinus*, since the males of the latter are more prone to migrate to the bases of trees or even into the soil for pupation. Hence the most striking difference observable between heavy infestations of *citri* and *lilacinus* is the much more "cottony" aspect of that of the former on account of the presence of large ovisacs and numerous male cocoons among the foliage.

Now with regard to microscopic characters, both *citri* and *lilacinus* belong to a closely related group within the genus which is distinguishable by the presence of a small but sharply defined chitinated bar on the ventral aspect of the anal lobes, together with the absence of auxiliary setae and of conspicuously grouped pores connected with the cerarii. Both species possess eighteen pairs of cerarii.

Structural differences observable in microscopic preparations are variable in character, and unless these happen to be markedly accentuated in one or two specimens an ample series becomes indispensable for correct determination.

If a series of specimens of each species be examined, it will be observed that despite a certain amount of variation the legs of *citri* are, on the whole, more slender than those of *lilacinus*, but not uncommonly individuals may be selected from each species whose legs are approximately similar in size.

Green and Laing find that the test whether the tarsi of the middle pair of legs are shorter (*citri*) or longer (*lilacinus*) than half the length of their respective tibiae to be of considerable use. Here, again, however, the margin of difference may sometimes be very small or non-existent.

On each of the anal lobes of *lilacinus* is a well defined chitinated area which stains deeply, but the corresponding areas on the anal lobes of *citri* stain very faintly or not at all; of course some uniformity in staining methods is necessary to make full use of this character.

Finally, the embryos of *lilacinus* reach a much more advanced stage of development before oviposition than do those of *citri*, and the staining and mounting of a few fully matured egg-laying females from whose body-cavities all the ova have not been removed will usually provide satisfactory confirmatory evidence.

Although *lilacinus* occupies as yet only a comparatively small area of the Colony, it has been recorded¹ from over eighty food-plants, which include the chief field and garden crop plants of the Colony. Its notoriety as a pest, however, has been acquired almost solely from the damage wrought in coffee plantations.

P. citri occurs in all the cultivatable parts of the Colony and may have a wider range of host-plants than is suggested by the following few records of the writer:—*Coffea robusta*, *Combretum splendens*, *Rhus* sp., *Citrus* spp., *Microglossa* sp., and an undetermined species of pea.

The Root-infesting Form of *Pseudococcus citri*.

In addition to the strain of *P. citri* which occurs on the aerial parts of coffee, there is also what appears to be a biological race which is confined to the roots. Although it is morphologically indistinguishable from the foliage-infesting form, repeated experiments have shown that it cannot be induced to live on the leaves or other aerial parts of *C. arabica*. Even individuals hatched from eggs placed on the foliage, which have thus not had an opportunity of feeding at the roots, fail to accustom themselves to this new situation.

There are differences in the waxy patterns of the dorsum in the root and aerial forms, the median longitudinal groove of the aerial form being absent in root-infesting individuals. The writer, however, is aware of the danger of basing conclusions entirely on differences in the secretory covering of these insects, and the distinction observable may be due entirely to differences of habitat.

The ovisac of the root-infesting form is voluminous and similar to that of the aerial strain, and the period of external incubation of the ova (157 examined) varied within the same limits as that of the foliage-infesting form, namely, from 7 to 13 days. It would seem that, in the absence of morphological evidence to the contrary, the root-infesting form must be regarded as a biological race of *P. citri*, although possibly some systematists with certain views regarding the concept of a species would be inclined to found a new species based on slight variations in the secretory covering and a profound difference in habit.

In any case this is not the first occasion in which forms very similar to if not identical with *P. citri* have been discovered to have root-infesting habits.

Morrison informs the writer (*in litt.*) that he has never been able to establish with certainty the identity of *P. vitis*, a species of mealybug which was closely involved with the grape-root disease complex, but from such information as was available to him he considered it to be identical with or very closely related to *P. citri*, as this species is now recognised. Further that there was in addition a question as to the final identity of *P. ficus* (Sign.), which was regarded by Lindinger (on what Morrison considered were perhaps inadequate grounds) as being identical with *citri*.

In view of the above it is of interest to record that the writer has discovered mealybugs, which seem identical with specimens collected from the roots of *C. arabica*, living in association with a species of *Eriosoma* on the roots of *Mentha piperita* (peppermint) in the grounds of the Scott Agricultural Laboratories, Nairobi.

What is morphologically the same species of mealybug has also been collected from the roots of *Indigofera* sp., *Combretum splendens*, *Solanum campylacanthum*, and *Solanum lycopersicum* (tomato). Whether individuals from each of these hosts are all to be regarded as belonging to the same strain of *P. citri* is still an open question.

The coffee root-infesting mealybug sometimes occurs in association with a fungus, whose compacted mycelia in advanced stages completely invests the mealybugs.

In other cases, which were for the most part confined to very young plants in coffee nurseries, no sign of a fungus could be detected. There seems to be a distinct correlation between excessive dampness of the soil and the incidence of coffee root mealybug in Kenya, and there is only one record in which this condition did not obtain. The foliage of an infested tree turns yellow, and where the mealybugs occur with the fungus they are capable of killing the host. Although the *citri* forms of root mealybug are widely distributed in East Africa on coffee and other hosts, the damage they have inflicted has never been sufficiently great to entitle them to more than the status of a minor pest.

Coffee root mealybug is most commonly attended by a hypogaecic species of ant, *Solenopsis punctaticeps*, Mayr, but other species which are not strictly hypogaecic, notably *Pheidole punctulata* and *Acantholepis capensis*, Emery, subspecies *canescens*, Emery, and *incisa*, Forel, have been observed to attend it also.

***Pseudococcus simulator*, sp. n. (fig. 1).**

This new species of mealybug aroused some interest when it was first examined, because there appeared to be a possibility that it might prove to be *Pseudococcus comstocki*, Kuw., the common mealybug of the Far East, which has a wide range of hosts in China and Japan. *P. comstocki* has penetrated into the United States of America at several points on both seaboard, and control measures have had to be employed against it.

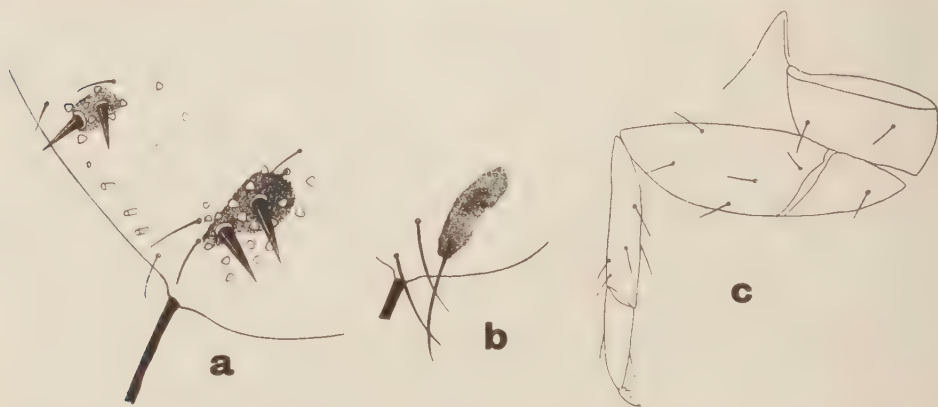


Fig. 1. *Pseudococcus simulator*, sp. n.: a, the penultimate and anal lobe cerarii. Dorsal aspect, $\times 80$. b, the ventral aspect of the anal lobe, $\times 80$. c, fore leg, $\times 80$.

The coffee industry of Kenya had already suffered from infestations of the introduced species of mealybug, *P. lilacinus*, and it was therefore a matter of some concern to ascertain finally whether *P. comstocki* had also obtained a foothold in East Africa.

Specimens of the species in question were originally collected by Mr. T. W. Kirkpatrick, Entomologist of the Amani Institute, Tanganyika, from Blue Mountain coffee in the grounds of the Scott Agricultural Laboratories during the month of April 1926, and later the same entomologist obtained a few more specimens from coffee (presumably *Coffea arabica*) in a plantation north-east of Thika, Kenya Colony.

Living specimens of this species of mealybug have not been seen by the writer, possibly owing to the masking effect of *P. lilacinus*, which has now penetrated into both areas from which the new species was collected. However, it may assist in field recognition to point out that photographs of the mealybug show that the median longitudinal groove, which forms part of the waxy pattern of the dorsum of *P. lilacinus* and to a lesser degree that of *P. citri*, is entirely absent in *P. simulator*.

Through the courtesy of Professor G. F. Ferris, of the Leland Stanford University of California, who gave me slides of *P. comstocki* collected in China, it has been possible to establish beyond doubt that the species of mealybugs collected by Kirkpatrick should be treated as new, the distinctive characters being as follows :—

The adult female with seventeen pairs of cerarii, of which the anterior two or three pairs possess three or four spines, the remainder with only two. The spines of the anal lobe cerarii are largest, but only slightly larger than the pairs immediately anterior to them. Auxiliary setae lacking, except on the two or three posterior pairs of cerarii. The number of cerarian trilocular pores varies from 4 to 6 in the middle region of the body and from 6 to 10 around each of the penultimate pairs of cerarian spines (fig. 1. *a*). On the ventral aspect of each anal lobe is a somewhat crescent-shaped chitinised area from which a long seta arises posteriorly (fig. 1. *b*). The anal lobe setae stout and about twice the length of the anal ring setae. The legs are shorter and stouter than those of the allied species, *P. comstocki*. The greatest breadth of the tibia of the foreleg always greater than one-third of its length (fig. 1. *c*). The second segment of the antennae always second longest. Trilocular pores, cylindrical ducts, and body setae numerous all over the derm. Multilocular pores present on the ventral surface of the posterior six abdominal segments. The body of the mature adult female varies in length from 1.80 mm. to 3.00 mm.

P. simulator has not been recorded in the Colony since it was originally collected in 1926 and is not of economic importance at present.

I am indebted to the Trustees of the British Museum for permission to examine the slides in its possession and my thanks are due to Mr. F. Laing, of the same Institution, for facilities kindly accorded.

***Pseudococcus virgatus*, Ckll.**

P. virgatus has now been recorded from all the coffee districts of the Colony, and although there is a certain amount of variation in the lengths of the antennal segments and the average size of mature females from different localities, there seems to be little doubt that they all belong to the same species.

P. virgatus is one of the easiest species of mealybugs to recognise in the field, chiefly because of the fine glassy filaments which are produced from a special type of gland-pore scattered over the derm. Just as these filaments are an almost invariable guide to its identity in the field, so the specially shaped gland-pores from which they arise are an almost certain diagnostic character of the species under the microscope.

P. virgatus appears definitely to prefer conditions below 5,000 ft., and the only general infestations recorded have occurred below this altitude.

In addition to *Coffea arabica* the writer has collected this Coccid from the following food-plants :—*Telanthra amabilis*, *Spathodea nilotica*, *Psidium guajava*, *Grevillea robusta*, *Pithecolobium saman*, *Mandevilla* sp., *Acalypha* sp., *Calpurnia* sp., *Sesbania* sp., *Poinsettia* sp., *Hibiscus* sp., and *Cassava*.

***Pseudococcus perniciosus*, Newst. & Willc.**

P. perniciosus occurs in all the coffee districts of the Colony, but no general infestation has been recorded. It is almost impossible to confuse this species with any other occurring on coffee in Kenya. Its globular shape, purplish black ground-colour, and buff-tinted wax and ovisac are very characteristic.

In addition to *Coffea arabica* the writer has observed it on species of *Acacia*. There are also records in the Agricultural Department of its occurrence on cotton, *Zizyphus spina-christi*, and *Albizia* sp.

***Pseudococcus longispinus*, Targ.**

What appears to be the first record of this species on coffee in Kenya came to hand last year from a plantation in the Cherangani district of West Kenya. Unfortunately only two adult specimens were obtained, and an effort was made to breed a sufficient number for purposes of identification. The mealybugs bred extremely slowly on *C. arabica*, and during the absence of the writer from the laboratory they were inadvertently destroyed.

However, this cosmopolitan species has such a characteristic appearance that there seems to be little doubt that microscopic preparations, when they become available, will confirm the presence of *P. longispinus* on *C. arabica* in Kenya.

Acknowledgments.

My thanks are due to Mr. T. J. Anderson, of the Agricultural Department, Kenya, for taking the photographs of *P. lilacinus* and *P. citri*.

The bulletin of the Agricultural Department, Kenya, entitled "The Common Coffee Mealybug," by Mr. T. W. Kirkpatrick, now of the Amani Institute, Tanganyika, formed a useful point of departure for most of the matters investigated in this paper.

References.

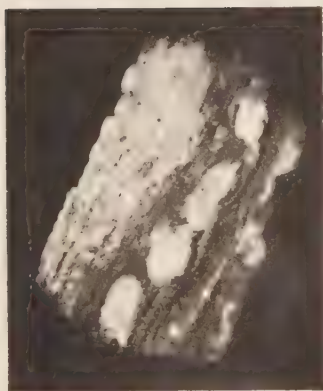
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 - ³ MORRISON, H. 1920. The Non-Diaspine Coccidae of the Philippine Islands with descriptions of apparently new species.—Philipp. J. Sci., xvii, pp. 147–202.
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EXPLANATION OF PLATE XIII.

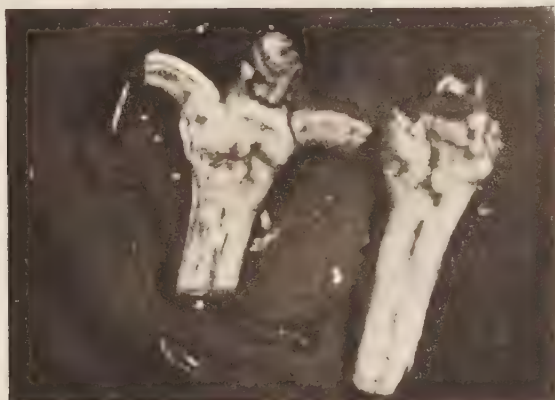
- Fig. 1. *Asterolecanium coffeae*, Newst. : a nearly mature female enclosed within the "test." The mesial fringe is represented by the dark median line. x 6.
- „ 2. *Asterolecanium coffeae*, Newst. : fully mature females enclosed within the "tests." The mesial fringes have disappeared. x 6.
- „ 3. Two nodes of *Coffea arabica* showing the pits caused by *Asterolecanium coffeae* (natural size).
- „ 4. *Pseudococcus lilacinus*, Ckll. : adult.
- „ 5. *Pseudococcus citri*, Risso : adult.



1



2



3



4



5.

Jeffersonia & Deane's *Jeffersonia*

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st April and 30th June, 1933, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance :—

Mr. E. G. AMARO :—6 Diptera ; from Angola.

Mr. M. AZIZ :—13 Culicidae and 20 larvae ; from Cyprus.

Mr. E. BALLARD, Government Entomologist :—70 Coleoptera and 2 species of Coccidae ; from Palestine.

Mr. S. N. BAX :—8,000 Formicidae and 8,000 Isoptera ; from Tanganyika Territory.

Mr. H. D. BELL :—100 Psychodidae ; from England.

Mr. H. J. BRÉDO :—1 Tachinid, 1 Curculionid, 1 Ichneumonid, and 1 Reduviid ; from the Belgian Congo.

Mr. S. C. BRUNER :—44 Coleoptera ; from Cuba.

Mr. J. CARROLL :—3 Parasitic Hymenoptera ; from the Irish Free State.

CHIEF ENTOMOLOGIST, PRETORIA : 18 Acrididae ; from South Africa.

Mr. G. H. CORBETT, Government Entomologist :—12 Diptera, 29 Coleoptera, 7 Parasitic Hymenoptera, 11 other Hymenoptera, 5 Lepidoptera, 1 species of Aphidae, 9 other Rhynchota, 2 Orthoptera, and 2 Dermaptera ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI : 170 Coleoptera and 572 Rhynchota ; from Kenya Colony.

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Mrs. V. DICKSON :—56 Coleoptera, 2 Hymenoptera, 42 Orthoptera, and 9 Trombididae ; from Arabia.

DIRECTOR OF PUBLIC WORKS, LAGOS :—70 Isoptera and a nest ; from Nigeria.

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Mr. S. GARTHSIDE :—4 Tenthredinidae and 10 larvae ; from England.

Mr. C. T. GIMINGHAM :—9 Parasitic Hymenoptera ; from U.S. America.

Mr. F. D. GOLDING, Government Entomologist :—287 Orthoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, BANGALORE : 2 *Haematopota*, 15 other Diptera, 32 Coleoptera, 1,700 Parasitic Hymenoptera, 10 other Hymenoptera, 11 Lepidoptera, 100 Isoptera, 2 Rhynchota, and 200 Mites ; from Mysore, India.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—162 Diptera, 18 Coleoptera, 97 Parasitic Hymenoptera, 3 Formicidae, 10 Lepidoptera, 17 Rhynchota, 3 Orthoptera, and 14 Dermaptera ; from South India.

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Mr. W. B. GURNEY :—6 Curculionidae ; from New South Wales, Australia.

Mr. A. M. GWYNN :—1 species of Aleurodidae, 11 other Rhynchota, and 8 Collembola ; from Trinidad.

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Mr. E. HARGREAVES, Government Entomologist :—7 Culicidae, 11 other Diptera, 116 Coleoptera, 4 Parasitic Hymenoptera, 15 other Hymenoptera, 25 Lepidoptera, 120 Thysanoptera, 1 species of Coccidae, 26 other Rhynchota, 33 Orthoptera, and 10 Nematoda ; from Sierra Leone.

Mr. W. V. HARRIS : 2 Coleoptera, 2 Lepidopterous larvae, 4 species of Coccidae, and 1 species of Aphidae ; from Tanganyika Territory.

Mr. J. D. HEPBURN :—4 Coleoptera ; from Northern Nigeria.

Mr. B. M. HOBBS :—14 Parasitic Hymenoptera ; from England.

Mr. H. J. HOCKINGS :—6 Diptera and 7 puparia, 6 Coleoptera, 50 Parasitic Hymenoptera, and 1 species of Aleurodidae ; from Queensland, Australia.

Dr. W. HORN :—623 Coleoptera ; from various localities.

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Mr. S. G. JARY :—2 Tenthredinidae ; from England.

Mr. H. B. JOHNSTON :—2 Coleoptera and 61 Orthoptera ; from Uganda.

Dr. W. A. LAMBORN, Medical Entomologist :—7 Tabanidae, 10 *Lyperosia*, 49 *Stomoxys*, 36 other Diptera and 9 early stages, 5 Coleoptera and 2 early stages, 11 Parasitic Hymenoptera, 2 other Hymenoptera, and 33 Lepidoptera and 21 early stages ; from Nyasaland.

Mr. R. A. LEVER, Government Entomologist :—16 Culicidae, 65 other Diptera, 333 Coleoptera, 13 Parasitic Hymenoptera, 320 Isoptera, 5 Thysanoptera, 3 species of Coccidae, 1 species of Aphidae, 42 other Rhynchota, 3 Orthoptera, 45 Spiders and 1,000 early stages, and 3 Birds ; from the Solomon Islands.

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Mr. J. E. M. MELLOR :—34 Parasitic Hymenoptera ; from England.

Mr. N. C. E. MILLER :—19 Coleoptera and 128 Orthoptera ; from Malaya.

Mr. H. M. MORRIS, Government Entomologist :—9 Culicidae, 17 other Diptera, and 12 Lepidoptera ; from Cyprus.

Mr. L. MORRISON :—1 Curculionid, and 1 Chalcid ; from New Zealand.

Mr. M. C. MOSSOP, Assistant Entomologist :—7 Diptera, 20 Coleoptera, 19 Parasitic Hymenoptera, 13 Lepidoptera, and 3 Rhynchota ; from Southern Rhodesia.

Mr. A. MOUTIA :—12 Diptera, 4 Coleoptera, 6 Parasitic Hymenoptera, 2 other Hymenoptera, and 160 Isoptera ; from Mauritius and Madagascar.

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Miss M. MUNRO :—2 Curculionid larvae and 20 Tenthredinid larvae ; from England.

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Dr. J. G. MYERS :—7 Diptera and 6 pupa cases, 32 Coleoptera, 7 Lepidoptera, 10 Hymenoptera, 6 species of Coccidae, 2 species of Aleurodidae, and 24 other Rhynchota ; from South America and the West Indies.

Mr. F. B. NOTLEY, Assistant Entomologist :—25 Coleoptera and 1 species of Coccidae ; from Kenya Colony.

PACIFIC ENTOMOLOGICAL SURVEY :—39 Diptera, 139 Coleoptera and 100 early stages ; from the Marquesas and Society Islands.

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Dr. S. V. PILL :—2 Lepidoptera and 259 Orthoptera ; from South Persia.

Mrs. M. C. RANT :—7 Orthoptera ; from Arabia.

Mr. Y. R. RAO :—7 Coleoptera, 3 Lepidoptera, and 100 Orthoptera ; from Baluchistan.

Mr. P. REGNIER :—47 Orthoptera ; from Morocco.

Dr. A. REYNE :—4 Coleoptera ; from the Dutch East Indies.

RHODESIA MUSEUM, BULAWAYO :—53 Coleoptera and 27 Rhynchota ; from Africa.

Dr. W. E. RIPPER :—114 Parasitic Hymenoptera ; from Austria.

Mr. A. H. RITCHIE, Government Entomologist :—41 Diptera, 276 Coleoptera and 70 early stages, 358 Parasitic Hymenoptera and 200 cocoons, 110 Lepidoptera and 22 early stages, 5 species of Coccidae, 1 species of Aleurodidae, and 34 other Rhynchota ; from Tanganyika Territory.

Dr. G. RUSSO :—3 Cecidomyiidae ; from Italian Somaliland.

Dr. G. SALT :—6 Parasitic Hymenoptera ; from Colombia.

Mr. G. M. SPOONER :—1,000 Parasitic Hymenoptera ; from England.

Mr. F. A. SQUIRE, Government Entomologist :—22 Diptera, 2 Coleoptera, 7 Parasitic Hymenoptera, 15 other Hymenoptera, 10 Lepidoptera, and 10 Rhynchota ; from British Guiana.

Mr. J. SUIRE :—3 Parasitic Hymenoptera ; from France.

Mr. J. S. TAYLOR :—20 Cecidomyiidae and 26 Parasitic Hymenoptera ; from South Africa.

Mr. R. W. E. TUCKER, Government Entomologist :—2 *Diatraea* egg-masses, attacked by 6 Gamasidae and 5 Chelifers ; from Barbados.

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Mr. F. W. URICH :—80 Coleoptera ; from Trinidad.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—146 Culicidae, 19 other Diptera, 129 Coleoptera, 41 Parasitic Hymenoptera, 104 Rhynchota, 13 Odonata, 10 Planipennia, and 50 Mites ; from the Sudan.

Mr. W. E. WHITEHEAD :—21 Mallophaga ; from Canada.

THE CAUSES AND IMPLICATIONS OF HUNGER IN TSETSE-FLIES.

By C. H. N. JACKSON, Ph.D., M.Sc., F.R.E.S.,

Survey Entomologist, Dept. of Tsetse Research, Tanganyika Territory.

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PREFACE.

In an effort to make the present paper as comprehensive as possible, the writer has drawn largely on the resources of his colleagues. Results taken from other workers are acknowledged in the text, but in addition the following acknowledgments must be made.

Thanks are due to Mr. C. F. M. Swynnerton, Director, to Mr. W. H. Potts, Senior Entomologist, and to Dr. T. A. M. Nash, Entomologist, Department of Tsetse Research, for reading through and criticising the earlier drafts of the paper. Their suggestions have been of great value. The writer wishes also to thank Mr. B. D. Burt, Botanist, and Mr. H. M. Lloyd, Entomologist, for much valued co-operation in the field work. Mr. Burt has also taught the writer all he knows about the botany of the country, and Mr. Lloyd has allowed the quotation of some of the results of his work on *Glossina swynnertoni* in Shinyanga. To Mr. S. Napier-Bax, Senior Field Experiment Officer, thanks are due for some stimulating discussion, and for permission to publish some results of his "Winter Effect" experiment. Thanks are due also to Mr. N. H. Vicars-Harris, Assistant Director, without whose smoothing of the official path much of the work would never have been done.

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To Mr. C. W. Chorley is due the writer's knowledge of the habits of *Glossina palpalis*, and the care taken by Mr. Chorley in demonstrating the behaviour of this fly in nature is gratefully acknowledged. Thanks are due to Dr. H. Lyndhurst Duke for the loan of two skilled native assistants, and to Mr. G. L. R. Hancock, Entomologist, Uganda, for his co-operation in such further study of *G. palpalis* as time allowed.

Finally the writer must thank Dr. R. A. Fisher, of Rothamsted, for his valued advice on statistical matters.

I. Introduction.

The aim of this investigation, carried on intermittently during the last few years as other work allowed, has been the elucidation of general problems of behaviour of tsetse-flies through a study of variations in their hunger condition.

The importance of the study is twofold. It may assist in the interpretation of observed variations, translating raw fly numbers into terms of tsetse economy, and it may give direct evidence on the condition of flies at different times and places, which evidence may have important bearings on attempts at fly control. More generally, it may assist the investigator to enter into the "mind" of the tsetse, and so to appreciate environmental changes from the tsetse's point of view.

Some elementary stages of the investigation, and some of the methods used, have been described already (1930, 1931). In the present paper it is proposed to bring the evidence up to date and to examine the implications of the subject. While it is not supposed that the last word has been said, the investigation has now reached a stage when its various parts can be collected together for mutual support, and the subject can be considered as a whole.

The writer is most familiar with *Glossina morsitans*, observations on which have supplied most of the data given in this paper. *G. swynnertoni* was studied at Shinyanga in 1927, 1930, and 1931, and was encountered at other times there and elsewhere. There have been fewer opportunities for studying *G. pallidipes*, and acquaintance with *G. palpalis* is founded on some ten days' work, when *G. brevipalpis* was met with also.

Most of the work has been done north of the Central Railway in Tanganyika Territory, but a short visit was paid to Uganda and to parts of Lake Victoria in 1932. In Tanganyika Territory observations have been made in seven Districts distributed through four Provinces, so that acquaintance with a reasonably wide range of conditions may be claimed.

II. Hunger Diagnosis.

1. Description of External Appearance.

Owing to the fact that in tsetse-flies the fat-bodies become maximally developed shortly after ingestion of a meal of blood, and thereafter decrease rapidly to a small volume before the really hungry stage is reached, it is possible to judge from the external appearance of flies the approximate stage to which digestion has proceeded. If in addition the length of the hunger cycle (period from feed to feed) for the particular time and place is known, it is possible to guess how many days have elapsed since the last meal, and how many are likely to supervene before the next one. This would not be possible if the tsetse retained well-developed fat-bodies for long after digestion had ceased. Owing to the complication of pregnancy in the female tsetse, the stage of digestion cannot be gauged from the external appearance in this sex, and it is necessary to resort to dissection.

The provisional classification of the hunger stages as given in 1930 may be quoted.

"Grade I. Abdomen distended with red or black blood visible from outside.

"Grade II. Abdomen distended in both directions, but without black blood visible from outside.

"Grade III. Abdomen not distended or wrinkled, usually white in appearance and not concave below.

"Grade IV. Abdomen beginning to wrinkle, sometimes distended by a gas bubble at the front end. Frequently straw-coloured on the ventral side.

"Grade V. Abdomen definitely concave or flattened, sometimes waferlike.

"Grade VI. Young (soft) flies."

It was noted that stage II was rare, and this stage was later amalgamated with stage III (1931). Apart from the young flies, therefore, there remained four stages, designated respectively gorged, replete, intermediate, and hungry. Up till recently the writer continued to use the old notation for these stages, which were therefore described, as I, III, IV and V. In 1932 it was pointed out by the Director and the Senior Entomologist that this arrangement made the subject unnecessarily difficult for other workers, and the writer agreed to change the notation to I, II, III and IV. On the suggestion of the Senior Entomologist, also, the young flies were removed from the classification and designated simply Y. Thus there remain

Stage I. Gorged.

Stage II. Replete.

Stage III. Intermediate.

Stage IV. Hungry.

Y. Young flies, which have not yet had their first meal.

It was found by the Director in 1929 that flies held to the light showed various amounts of opacity in the abdomen, and these appearances have been correlated to some extent with the hunger stages. These and other investigations have made it possible to amplify the foregoing descriptions of the hunger stages, as below.

Stage I. Gorged flies.

The condition immediately after engorgement is described by Newstead & Davey (1914) and by Bruce & collaborators (1915). After a full feed the abdomen is at first dull red, the white tracheae being very conspicuous. The abdomen is considerably swollen, and the genitalia of the male are forced upwards and backwards.

The red colour disappears, remaining longest towards the anterior end, and a small bubble of gas appears in the crop. The red is replaced by deep blue-black, and the tracheae and whitish segmental borders remain very conspicuous.

Subsequently the abdomen resumes more normal proportions. The blue-black colour remains up to the end of this stage as a small patch ventrally, usually towards the anterior end. The sides of the abdomen are deep grey-black between the lighter segmental borders; the tracheae remain conspicuous; the ventral surface is creamy-grey.

The translucent appearance shows that the abdomen is entirely or almost entirely opaque; some red blood is usually visible at the anterior end.

Stage II. Replete.

The abdomen is usually very slightly swollen; at any rate there is no concavity. The grey-black colour remains about the spiracles and the lateral ends of the sternites, these dark patches remaining conspicuous at the sides of the abdomen. The tracheae are less conspicuous than in Stage I. A small amount of gas may be present in the crop, detected by pushing forward the genitalia. The gas bubble is never very large. The abdomen feels firm when held between finger and thumb, its shape remaining unaltered by moderate pressure. This is owing to the bulk of the contained fat-bodies, which are maximal at this stage. If the abdomen is swollen it may be somewhat round and short. The colour of the ventral side is milky-grey. There may be some suggestion of straw-colour posteriorly. There is no wrinkling of the ventral surface.

If the fly is held to the light the abdomen is seen to be from two-thirds to entirely opaque, measuring from the proximal end of the genitalia to the anterior end of the abdomen. The clear area is at the anterior end, where red blood is sometimes discernible.

Stage III. Intermediate.

The abdomen is not swollen, or, if it is, the swelling is due to a large gas bubble in the crop, which gives a silvery colour to the abdomen, and can be demonstrated by gently pressing forward the genitalia. There may be slight concavity. The dark lateral patches have become light grey and inconspicuous, and the segmental borders and tracheae are inconspicuous also. The abdomen has not the firm feel characteristic of stage II. The posterior half may be more or less distinctly straw-coloured. There is very frequently some wrinkling of the ventral surface, especially posteriorly, due to the sinking in of the abdominal wall between the segmental borders; the posterior segments may be telescoped into one another.

Held to the light, the abdomen is from one quarter to two-thirds opaque, occasionally almost entirely clear. There is no trace of red blood, and the opacity usually is not very deep.

Stage IV. Hungry.

The abdomen is definitely concave or flattened. The genitalia are drawn forwards by the constriction of the ventral surface. Gas usually is not evident. The tracheae are quite inconspicuous, and the dark lateral patches are reduced to vestiges most conspicuous about the first inter-segmental border. Generally, in earlier examples of this stage at least, the first two abdominal segments are less flattened and lighter in colour than the succeeding ones, and may show wrinkling. The abdomen is straw-coloured on the ventral side.

The translucent appearance usually shows from one-third or one-quarter opaque to entirely clear. The colour of the abdomen held to the light is yellow.

Y. Young Flies.

The underside of the abdomen may be either very much flattened or swollen with gas. In the first case it is pale buttery colour, in the second dead white. Mr. Potts gives as a character the utterly empty feel of the abdomen. The dark lateral patches are absent even from the region of the first inter-segmental border. The underside of the thorax is pale powder-blue, very distinct from the dull grey-blue of adult flies.

There can be no mistaking a young fly held to the light. The whole of the abdomen is clear white with no trace of yellow.

The ptilinum of the young fly can be expressed with forceps. Mr. Potts has shown that the expressibility of the ptilinum does not necessarily show that the fly has not fed. In the young fly the ptilinum is at first white; in older flies orange or brown.

The origin of gas in flies is not known. A gassy condition of the abdomen can be produced artificially, as shown by Mr. Lloyd, by tapping a fly rapidly and repeatedly on the frons.

The diagnosis of hunger, which from the above amplified description might at first seem somewhat complicated, can be simplified as follows.

If a fly is diagnosed correctly as stage I or stage II the abdomen must be neither wrinkled nor concave ventrally, nor must it be straw-coloured; and it must be two-thirds or more opaque when held to the light.

A fly correctly diagnosed as stage IV must be definitely concave or flattened, with the underside of the abdomen straw-coloured, yellow when held to the light.

Any fly which does not fit either of the above descriptions, and is therefore intermediate between the two, is assigned to stage III.

Flies fitting the first description, and also showing red or blue-black blood from the outside, are assigned to stage I.

2. Description of Internal Appearance.

Dissections carried out in collaboration with Mr. Potts in 1929 and 1931, and a few more done later by the writer, are the foundation of the following notes, and concern *Glossina morsitans* only. A few dissections done by the writer using *G. palpalis* gave generally similar results.

A nick is made with fine scissors or a scalpel on either side of the abdomen immediately anterior to the genitalia. The genitalia are then held by a blunt pair of forceps and drawn gently backwards until the posterior extremity is free externally from the anterior portion. The abdomen is cut off at the base and placed in saline on a slide, ventral side uppermost. A needle is placed on the genitalia, and another just inside the dorsal surface at the anterior end. The two needles are then moved apart until the gut is unravelled and exposed. The fat-bodies are dissected off and set aside for examination.

The mid-gut is divisible into three parts, which may be designated MG.1, MG.2, and MG.3. Their histology has been described by various authors, of whom Wigglesworth (1929) is the most recent. From sections cut by the writer the salient features are seen to be as follows.

MG.1. A long, thin-walled, distensile tube lined with lightly-staining columnar epithelial cells and surrounded by a narrow band of circular muscles. When the tube is not distended the lumen is almost blocked for part of its length by two columns of giant cells with very large nuclei.

MG.2. A distensile section shorter than MG.1, and sharply separated from it, lined with deeply-staining cells, forming a less deeply columnar epithelium. The irregular inner extremities of these cells reach inwards towards the peritrophic membrane and its contained blood.

MG.3. A practically non-distensile section, about two-thirds the length of MG.2, and not sharply divided from it. The histology is similar to that of MG.2, except that the epithelium is somewhat more deeply columnar.

Macroscopically, MG.1 appears when empty of blood as a delicate, colourless tube of uniform width, the giant cell zone being conspicuous. About the junction with MG.2 there are frequently some carmine granules in the wall. MG.2 when distended is fairly readily separable from MG.3, and usually both contain coloured detritus. MG.3 extends to the junction of the two ducts of the four Malpighian tubules.

The ectodermal hind-gut is non-distensile, and except the rectum usually creamy or colourless.

The fat-bodies are mostly situated about the anterior end of MG.2 and about the genitalia.

The description of the mid-gut and fat-bodies in the various hunger stages follows.

Stage I. Gorged.

MG.1 usually contains bright red blood, at least a small amount, and immediately after a meal is greatly distended. Later, distension disappears and only traces of red blood remain. MG.2 contains red blood anteriorly; the posterior part is deep black. There is considerable distension. MG.3 is deep black and undistended. The fat-bodies have not reached maximal development.

Stage II. Replete.

MG.1 is usually empty and colourless. MG.2 contains microscopically recognisable red blood. The anterior end is red, the posterior three-quarters deep black, as is MG.3. MG.2 is more or less distended; MG.1 and MG.3 are not. The fat-bodies are maximally developed.

Stage III. Intermediate.

MG.1 is colourless and not distended. MG.2 very seldom contains red or recognisable blood. The contents may be brown or dark green, seldom black. MG.3 is usually greenish-black, sometimes deep black. Distension of MG.2 is slight or absent. The fat-bodies are somewhat reduced.

Stage IV. Hungry.

MG.1 and the anterior part of MG.2 are colourless. The posterior part of MG.2 and all of MG.3 may be brown, dark green or colourless. Distension is absent. The fat-bodies are reduced and many are pyriform.

Y. Young Flies.

In young flies the only colour in the gut is apple-green. There is no distension. The fat-bodies show minimal development, and all are pyriform.

From the foregoing account it is evident that there is considerable agreement between the external, the translucent, and the internal appearances of flies in the various stages.

Flies kept in captivity undergo an irregular hunger cycle and will not be found to agree with the above descriptions. Thus in captivity it will be found that flies become very thin a day or two after a feed, although blue-black blood actually remains visible down the middle line of the abdomen on the ventral side. Apparently, also, a small percentage of flies in nature undergo an irregular hunger cycle, perhaps after incomplete feeds; but in a general way the above descriptions will be found to hold good. Flies about which there is any doubt are conveniently assigned to stage III, the intermediate stage.

It may be added that stages I, II, III and IV of this classification correspond roughly to the gorged, fed, thin, and starving stages recognised in the Ecological investigation carried on by Messrs. Phillips, Potts and collaborators at Kikori in Tanganyika in 1929-31 (Potts 1930; Scott 1931) except that part of the "thin" stage of those workers would be placed in the present writer's stage III, and part in stage IV, together with the "starving" flies.

3. *Estimation of the Hunger.*

Two methods of estimating hunger from samples have been in use, but the better and simpler method only need be described. The estimate is known as the Mean Hunger Stage (M.H.S.). Stage I flies are neglected, on the grounds that, though now gorged with blood, they have very lately been hungry, and tend to remain in the same locality as the hungry flies for some time after the meal. Their numbers in ordinary samples are in any case small. Females are neglected because, although their appearance in samples is determined very largely by their hunger, replete females seldom showing themselves, yet their frequency is apparently determined also to some extent by the total fly density, a lower proportion of females being associated with a higher density of males. Young flies also are excluded from the estimate, since although they are certainly hungry their numbers must be strongly affected by the emergence rate, which varies with the season.

The mean stage of the remaining male flies (stage II, III and IV) is then found by multiplying the number in stage II by 2, the number in stage III by 3, and the

number in stage IV by 4. The sum of the products is divided by the total number of flies in these three stages contained in the sample. Two decimal places should be worked. Thus :—

Males :	I	II	III	IV	Y	Females :	Mature	Y
	5	23	85	18	1		3	2
M.H.S. = $\frac{2 \times 23 + 3 \times 85 + 4 \times 18}{23 + 85 + 18} = 2.96$								
Males :	I	II	III	IV	Y	Females :	Mature	Y
	0	0	5	10	4		12	3
M.H.S. = $\frac{2 \times 0 + 3 \times 5 + 4 \times 10}{0 + 5 + 10} = 3.67$								

The great advantage of this method is that the meaning is conveyed at sight, the possible values for the estimate varying from 2.00 to 4.00, with hungrier values above 3.00 and repleter values below it.

The types of fly community for which different hunger estimates are characteristic are suggested in the table on page 451.

4. *The Diagnosis of Hunger by Fly Behaviour.*

As stated by Nash (1930), flies are usually collected both off the catching party and off the ground and surrounding vegetation. It has been found that the inclination of a fly to settle on the catchers or on the ground or vegetation is associated with the state of hunger of the fly, and further that hungrier individuals will usually sit head-upwards and repleter flies head-downwards when settling on the catchers. The behaviour of the several hunger stages in this respect is described.

Stage I. Gorged.

Flies in this stage seldom attack the catchers, preferring to settle on the ground. Those that do alight on the catchers may assume either the head-up or the head-down position; apparently individuals containing a very great quantity of undigested blood prefer the head-up attitude. They will not attempt to feed.

Stage II. Replete.

These flies are not more inclined than are stage I flies to settle on man; when doing so they usually rest head-downwards. They do not attempt to feed on man.

Stage III. Intermediate.

When alighting on man, flies in this stage may settle either head-up or head-down, but most prefer to settle on the ground. They will sometimes feed on man.

Stage IV. Hungry.

Hungry flies seldom settle on the ground, preferring to attack the catchers. They alight on man nearly always head-upwards, and most are willing to feed. Females behave in the same way.

Y. Young Flies.

These behave as hungry flies. Their flight is less noisy and determined than that of mature individuals. As noted by Nash (1930), they are sometimes difficult to capture.

The following tables show the behaviour of *Glossina morsitans* in the presence of a party of catchers in different seasons of the year. In the longer-grassed season fewer flies in the several stages are caught off the ground and vegetation, but otherwise they show very good agreement with the remarks just made.

Stages of males	Attacked head-up	Attacked head-down	Off ground
	1. December to April.	Grass long.	
I	16	18	60
II	17	50	168
III	88	74	360
IV	134	24	24
Y	43	6	4
Females	111	4	4
	2. July to August.	Grass shorter.	
I	10	11	22
II	14	21	64
III	84	87	180
IV	112	31	11
Y	24	3	0
Females	129	5	3
	3. October to November.	Grass short.	
I	0	2	59
II	1	7	141
III	33	52	327
IV	136	62	46
Y	32	9	2
Females	178	25	12

Dr. Nash has pointed out in conversation that on very hot days flies avoid settling much on the ground, and no doubt the above figures would have been affected by this cause, were it not that they were taken in the afternoons when the ground may have been cooler, or the slanting sun less fierce upon it.

It is conjectured that the hungry fly sits head-upwards on its host in anticipation of the weight of blood which its abdomen is about to contain. The replete male fly probably settles head-downwards in order to observe the approach of females, which usually fly just above the ground when following the party in order to attack (Lamborn, 1915; Swynnerton, 1921; Nash, 1930). The preference of the female fly for the head-up position has been made use of in the construction of traps for tsetse-flies (Swynnerton, 1933). *Glossina pallidipes* and *G. brevipalpis*, which practically never appear to man unless hungry, sit in the head-up attitude on man.

As to the actual position selected for attack, *Glossina morsitans* and *G. swynnertoni* attack the human host at any height from the ankle to the head. *G. pallidipes* and *G. brevipalpis* seem to attack lower down, the first at any rate seldom biting above the knee. The attack of these two species is clumsy and the bite distinctly painful; *G. swynnertoni* has the least clumsy attack and the least painful bite of all four species, *G. morsitans* being intermediate in these respects. Probably in all species the young fly's bite is the most painful. *G. palpalis* is more elusive, under certain conditions, than any of these species; it has not been seen by the writer to attack in any but the head-up position. Its bite appeared to be about as painful as that of *G. morsitans*.

The fact that, with *G. morsitans* at least, repleter flies tend to settle on the ground and hungrier flies attack the catchers is useful on rapid fly surveys, when the observer can get a rough idea of the constitution of fly communities in sites traversed without stopping to examine personally every fly caught. The following table may prove useful in this connection. An observer unfamiliar with the appearance of flies in the different hunger stages may also find the table useful as a very rough check on his diagnosis of hunger from samples.

Hunger and Behaviour of Flies in Different Communities (G. morsitans).

Fly community			Fly condition		M.H.S.	Percentage mature males on ground
Home	...	...	Replete	...	2.4	90
..	...	...	..	...	2.5	90
..	...	...	..	...	2.6	90
..	...	...	..	...	2.7	90
..	...	...	..	...	2.8	85
..	...	...	..	...	2.9	80
..	...	...	..	...	3.0	80
Mixed	...	...	Slightly hungry	...	3.1	75
..	...	...	..	...	3.2	70
Feeding ground	...	...	Rather hungry	...	3.3	60
..	..	...	..	..	3.4	50
..	..	...	Hungry	...	3.5	40
..	..	...	..	...	3.6	30
..	..	...	..	...	3.7	20
Open feeding ground	...	...	Very hungry	...	3.8	10
..	..	...	..	..	3.9	0
..	..	...	..	..	4.0	0

The community types referred to in the first column were described in an earlier paper (1930) and will be treated more fully later. By "open feeding ground" is meant open country into which flies may stray; in such situations the hungriest flies are found, although it is doubtful whether they ought strictly to be called feeding grounds. Values of the Mean Hunger Stage below 2.4 are very seldom found; hence the table starts with this value. As already stated, these figures must not be taken too exactly. The intention is to suggest the sort of condition that the writer has found to be of ordinary occurrence, more especially in the dry season.

5. *Hunger and Following Habits.*

Hungry flies tend to follow their hosts more persistently than do repleter flies. In the following table are given particulars of flies (*G. swynnertoni*) marked in three separate localities and of flies which were re-marked on following the catching party after the ordinary marking had ceased on emergence from the localities.

The first series is founded on 37 following flies, the second on 47, and the third on 15. The low female and young percentages in the third series of following flies may

perhaps be ascribed to this cause. Otherwise it is apparent that flies following out of the localities are distinctly hungrier than flies marked in them. The numbers marked in the respective sites were 1,467, 623 and 430.

M.H.S.		Females %		Young fly %	
In site	Following	In site	Following	In site	Following
3-08	3-625	18-3	21-7	18-3	21-7
3-41	3-54	28-6	34-0	28-6	38-3
3-42	4-00	31-9	26-7	21-2	20-0

Flies taken on motor-cars passing through fly-belts are always very hungry, probably owing to this effect.

The point is of importance in taking fly samples, because if the catching party walks through the bush without catching, and then stops to take a sample, this will include an inordinate number of hungry flies, and the hunger estimate will be too high for the locality. If samples are to be taken at discontinuous intervals it is necessary first to catch off the following flies.

6. Summary of Hunger Diagnosis.

This section may be rounded off by a table summarising hunger diagnosis by the external and internal appearances of flies.

Summary of Hunger Diagnosis (*G. morsitans*).

Males	Stage I	Stage II	Stage III	Stage IV	Y
<i>External Appearance</i>					
Red or blue-black blood ...	*				
Distension of abdomen, not due to gas	*	†			
Gas, causing distension ...			†		†
Concavity or flatness ...				*	†
Firm feel of abdomen ...		*			
Wrinkling ...			†	†	
Lateral patches dark ...	*	*			
Creamy-grey ventrally ...	*	*			
Straw-colour ventrally ...			*	*	
Buttery-colour ventrally ...					*
Ptilinum eversible, and soft, soapy feel					*
<i>Translucent Appearance</i>					
Fraction of abdomen opaque ...	All	$\frac{2}{3}$ or more	$\frac{1}{4}$ to $\frac{2}{3}$	None to $\frac{1}{3}$	None
<i>Internal Appearance</i>					
Recognisable blood† ...	*	*			
Distension of MG.1 ...	†				
Distension of MG.2 ...	*	*	†		
MG.2 all black or red ...	*	*			
MG.2 green or brown ...			*	*	
MG.3 black or very dark ...	*	*	†	†	
Fat-bodies ...	Variable	Good	Moderate	Poor	Very poor
<i>Usual Attacking Attitude</i>					
Head-up ...	†		†	*	*
Head-down ...	†	*	†		
<i>Attacking or caught off Ground</i>					
Usually attacking ...			†	*	*
Usually caught off ground ...	*	*	†		

* = positive.

† = sometimes positive.

‡ Microscopically.

III. Hunger and Fly Distribution.

1. *Glossina morsitans*.

Breeding of *Glossina morsitans* has been described by Nash and the writer (both 1930) as occurring mainly in the *Berlinia-Brachystegia* woodland of both eastern and western parts of the Kondo District of Tanganyika Territory. Nash also notes that the fly does not favour *Combretum* savannah as a breeding-ground in Eastern Kondo, but that it will breed in woodland of *Acacia usambarensis* if this tree is growing on sandy soil. The breeding area is termed by Nash the *true habitat*, and by the writer the *home*.

In the home, both authors found that female flies appeared in relatively small numbers to man, and that young flies also were taken in smaller proportion than elsewhere. These results were in agreement with the finding that the mature males which formed the great majority of flies caught in the home, were very much less hungry than those taken outside it. Hungry flies of all kinds evidently did not remain in the home.

Feeding-grounds, populated by hungry flies, with a high percentage of females and young flies, were recognised in a variety of situations. In Eastern Kondo (Nash) the feeding-grounds were usually larger and more open; in the western parts of the District most of the feeding-grounds were found in small drainage valleys, but they occurred in more open places as well. These differences are easily explained by differences of topography and vegetation; perhaps also the denser game population in Eastern Kondo may have allowed the fly to make use of less compact feeding-grounds.

The above findings imply that the deciding factor in determining the broad distribution of *G. morsitans* is suitable vegetational conditions, or the associated physical conditions, for the home. Granted these, very various conditions will serve to form suitable feeding-grounds.

Throughout most of the western part of the Central Province of Tanganyika Territory, in the Tabora District, in Kahama, and in southern and western Nze District, the writer found *G. morsitans* making its home only in *Berlinia-Brachystegia* woodland. The dominant species of trees in this type are *Berlinia globiflora*, *Brachystegia itoliensis*, and *B. edulis*. In Eastern Kondo Nash described woodland of *Brachystegia microphylla* growing on the face of the escarpment as being more favourable as a true habitat than *Berlinia* growing below.

About Kazikazi, in the western part of Manyoni District on the Central Railway, *G. morsitans* made its home both in *Berlinia-Brachystegia* woodland surrounding the great thickets and in the *Terminalia-Combretum* transition between the *Berlinia-Brachystegia* and the drainage valleys running below. In parts of this country the *Terminalia-Combretum* comes right up to the thicket, the *Berlinia-Brachystegia* zone being omitted, and in such places the fly was found living normally, often a mile or more from the nearest *Berlinia-Brachystegia*.

In northern Nze District (Tabora Province) a more marked dissociation from *Berlinia-Brachystegia* was found. Here *G. morsitans* inhabits a block of country some twenty miles square from which these trees are entirely absent. Dominant species varied very much, but among the most important were *Ostryoderris stuhlmannii*, *Lonchocarpus capassa*, *Sclerocarya birrea* var. *multifoliolata*, *Terminalia sericea*, and *Cassia abbreviata*, and there was a sprinkling of *Acacia roovumae*, *A. goetzii*, and *A. pallens*. The incursion of *G. morsitans* into this area is recent (Swynnerton, 1925). It appears to have spread in from the *Berlinia-Brachystegia* woodland to the west, and perhaps also from the south.

In Ankole, in south-western Uganda, *Berlinia-Brachystegia* is absent. *G. morsitans* was seen breeding in a narrow zone between the bare hillsides and the valleys

below in a vegetation type dominated by *Acacia hebecladoides*, with numerous ant-hill thickets of *Rhus* and other species. Small trees of *Acacia stenocarpa* were numerous. The writer understands from the Director that a similar condition obtains in the Bukoba Province of Tanganyika, facing Ankole across the Kagera River.

In the Lango region where the Nile emerges from Lake Kioga in the Northern Province of Uganda, the home of *G. morsitans* is again found in the absence of *Berlinia-Brachystegia*. Dominant trees are *Combretum apiculatum*, *C. fischeri*, both growing unusually tall, and *Terminalia* sp. The grass growth is longer than in other areas visited. Large thickets of *Harrisonia abyssinica*, *Rhamnus* sp., and *Acacia pennata* are characteristic.

From the foregoing observations it would appear that through most of Tanganyika Territory (the writer has been told that conditions are similar south of the Central Railway) *G. morsitans* would appear to make its home and to breed in woodland dominated by *Berlinia-Brachystegia*. However, in certain places *Terminalia-Combretum* and similar broad-leaved woodland will suffice. In southern Uganda this fly was found living and breeding in *Acacia* woodland with small thickets; this District has a higher rainfall than the country examined in Tanganyika.

It is important to note that in all cases the situations where breeding was found to occur were characterised by catches of flies showing low hunger values and low female and young fly percentages.

Considerable variation in feeding-grounds was found. Thus, as already stated, the feeding-grounds in Eastern Kondoa are for the most part large, open areas on alluvial soil. But here also drainage valleys descending the escarpment through woodland of *Brachystegia microphylla* were found to contain hungrier flies.

Throughout the Western Kondoa fly-belt, extending from the Bubu River westwards into Singida District, the typical feeding-ground was the narrow drainage valley descending between low hill spurs, but feeding-grounds were found in more open places also, resembling those in Eastern Kondoa.

Farther west again, feeding-grounds were formed by similar but shallower drainage valleys running between *Berlinia-Brachystegia* and *Terminalia-Combretum* woodland lining the spaces between the great blocks of thicket. Here again more open swamps also contained hungry flies.

In the north part of Nzega District and in Kahama District conditions were different in association with a different type of drainage valley supporting a taller grass growth, but in some of these valleys hungrier flies were found; in north-eastern Nzega large areas of thorn scrub alternating with open spaces resembling the diffuse feeding grounds of Eastern Kondoa were found also to contain hungry flies.

In southern Uganda feeding-grounds were not located by the writer, owing to unfavourable weather conditions; however, according to Mr. Kennedy they occurred in the expected situations. In the Lango area of the Northern Province of Uganda hungry flies were found principally in jungle of small and larger *Acacia* trees (*A. campylocantha*, *A. hebecladoides*, *A. sp. cf. stenocarpa*, *A. seyal*) among which were small patches of open ground bordering a long-grassed swamp. Here again, weather conditions were not favourable for locating smaller and less obvious feeding-grounds.

In every area visited feeding-grounds were found to occur along motor roads.

2. *Glossina swynnertoni*.

Having studied this species for periods aggregating about a year in all, the writer is less familiar with it than with *G. morsitans*, but Mr. Lloyd, who took over from the writer in Shinyanga, has been able to confirm or amend his preliminary suggestions. It is hoped that a complete account of the bionomics of *G. swynnertoni* will be published by Mr. Lloyd. Here it is intended to describe very briefly its habitat and feeding habits, so far as they are known.

The most favoured breeding-areas cannot be said to be known, but the flies themselves seem specially addicted to "hard-pan" soils about the head of drainage valleys, sandier patches occurring about the ant-heaps, and to similar "hard-pan" stretches running alongside the denser vegetation on rivers. Small trees of *Lannea humilis*, *Commiphora schimperi*, and *Acacia drepanolobium* are characteristic, often with *A. mellifera* and *Terminalia stuhlmannii* and the small shrub *Maerua trichophylla*. About the ant-heaps are thickets of *Grewia bicolor*. Grass growth is generally short and scanty, being replaced by *Justicia* sp.

Large areas of the country are covered with woodland of *Ostryoderris stuhlmannii*, *Commiphora fischeri*, *C. pilosa*, *Acacia benthamii*, *Strophanthus eminii*, *Combretum splendens*, and *C. zeyheri*, on laterite soils. In this type, fly is very much less common than on the "hard-pan," the difference in density being often so marked as to justify the term "concentrations" for the fly communities of the "hard-pan" patches.

These conditions were observed in Shinyanga, where, as the result of measures instituted by the Director of Tsetse Research in 1924 (Swynnerton, 1925) fly has very much decreased in recent years. According to the Director, the present concentration of *G. swynnertoni* on the "hard-pan" was less marked when fly was more numerous. On the other hand the writer noticed a distinct preference of this fly for the "hard-pan" soils as far back as 1927, when fly could still be taken at the rate of 100 an hour in many places. In other parts of the country (the Wembere Steppe, the Meatu Plains, and the western edge of the Masai Steppe) where the writer has encountered *G. swynnertoni*, it has always been in numbers too small to throw light on this point.

On the "hard-pan" patches fly shows low hunger values, and low percentages of females and young flies. On the analogy of *G. morsitans*, therefore, these patches may be termed the home, although it is still uncertain where most of the breeding occurs.

The only specialised feeding-grounds that could be found were on roads, fire-breaks, and the edges of artificial clearings or of open country, and even here fly were only found in any numbers at seasons of the year when they were really hungry. These places, of course, were characterised by higher hunger values and higher female and young fly proportions.

Dr. Nash has suggested (in a Departmental minute) that *G. swynnertoni* feeds throughout the infested bush, including the "hard-pan" patches, and that within this general feeding area true breeding-areas occur wherever thickets, in which these flies breed, are sufficiently numerous. In opener country, where thickets are scarcer, hungrier flies will predominate owing to the absence of the replete fly element, which he suggests, on the analogy of *G. morsitans*, is confined to the breeding-areas. The writer is in general agreement with this view; but an experiment (see page 479) performed by Mr. Bax in 1931 seems to suggest that some vegetational quality other than the mere presence of thickets is necessary to harbour a population of replete flies. Mr. Bax defoliated by poison the trees in an area of "hard-pan" selected as a typical and well-populated replete-fly area. The thickets, although slashed, remained *in situ* until the grass fires some months later. But the replete fly element disappeared from the poisoned area, while remaining in a control plot alongside, before the destruction of the thickets by fire. It is conjectured that such canopy as is afforded, even in the earlier part of the dry season, by such small trees as grow there is essential to the existence of the replete fly community on "hard-pan" soils.

3. *Glossina pallidipes* and *G. brevipalpis*.

Nothing appears to be known of the relation of the distribution of these species to their feeding habits.

4. *Glossina palpalis*.

As this fly appears to afford in one respect an interesting contrast to *G. morsitans*, the writer may be excused for mentioning it after a very slight acquaintance.

Mr. Chorley very kindly demonstrated to the writer some features of its behaviour on Bulyingugwe Island near Entebbe, and explained the nature of its communities. Subsequently the writer was able to confirm some of these facts for himself.

This species makes what Mr. Chorley terms its rest haunts in a heavily-canopied strip of vegetation some few yards back from the lake shore. In this type *G. palpalis* may be seen sitting about on trees, leaves, and rocks, frequently in small sunlit patches. Hunger estimates obtained from the rest haunt proved to be low, and females and young flies few.

Feeding haunts were shown by Mr. Chorley to occur in small glades situated in the narrow strip between the rest haunt and the lake shore. In these sites it was found that higher hunger estimates were obtained, and flies frequently attacked the party. Among these flies was a fair proportion of females and young individuals. It was in such situations that Mr. Chorley placed his traps.

Breeding-haunts were described as being of two kinds. At high lake-level the fly-beaches are covered. At these times flies form temporary breeding-haunts in a variety of scattered situations. At low lake-level breeding occurs in specialised situations (permanent breeding-haunts) along the upper edges of the fly-beaches, which then form feeding-haunts also.

Thus the breeding-haunt of *G. palpalis* may be either scattered through a variety of situations or concentrated in a specialised portion of the feeding-haunt; with *G. morsitans* the breeding-haunt is identical with the rest-haunt, the two together being termed the true habitat or home. Both types of breeding-haunt of *G. palpalis* were demonstrated to the writer, the fly-beaches being covered on Bulyingugwe Island and exposed on part of the mainland nearer Entebbe, where Dr. Duke's fly-boys uncovered in the writer's presence a spectacular number of puparia.

Mr. Chorley points out that the behaviour of *G. palpalis* along rivers will not necessarily be found to be the same as its behaviour on the lake shore.

5. General.

The following table summarises the nature of the rest-haunts (replete-fly areas), breeding-haunts, and feeding-haunts of *G. morsitans*, *G. swynnertoni*, and *G. palpalis* so far as they are known to the writer in the countries visited.

Species of <i>Glossina</i>	Rest-haunt	Breeding-haunt	Feeding-haunt
<i>G. morsitans</i> ...	Usually woodland of <i>Berlinia-Brachystegia</i> ; occasionally, as in Uganda, other types of woodland	As for rest-haunt	Drainage valleys, roads, edges of open country, or large swamps if not too long-grassed
<i>G. swynnertoni</i> ...	"Hard-pan" soil with small trees and thickets	Unknown: perhaps same as rest-haunt	Roads and edges of open country, or as for rest-haunt
<i>G. palpalis</i> ...	Under heavy canopy in zone a little back from lake-shore	Either very scattered or part of feeding-haunt (fly-beach)	Small opener spaces near water, or fly-beaches

That females really do occur in substantial numbers in the home of the fly was suggested by some experiments with bait cattle on *G. morsitans* described in 1930. Since that time it has been found that traps designed to catch only hungry flies will catch about 50 per cent. females even in the home. The same was found to apply to *G. swynnertoni*, when this species was being trapped experimentally in its home in January 1931. At this time and place about 50 flies an hour could be caught with

nets (M.H.S. 2.6 to 3.0) of which only about 1 per cent. were females, but of flies caught in the traps the females were over 50 per cent. It was noticed repeatedly that, when natives were sent to "walk up" flies to the traps for observation of their behaviour, a number of females would appear on the traps from the following swarm of flies, although natives with nets could catch almost nothing but males. The proportion of pregnant individuals among females caught in traps is always higher than when flies are collected in the ordinary way.

IV. Hunger and Fly Movements.

This section is concerned not with fly migrations, but with movements of individual flies to and fro within the fly-belt. These to-and-fro movements are of great importance in the economy of the tsetse, and are intimately associated with the onset and the satisfaction of hunger.

In two earlier papers (1930 and 1931)* dealing with *Glossina morsitans* and *G. swynnertoni* respectively, evidence in favour of the feeding-ground theory was put forward. Apart from indirect evidence, the essential point was that flies marked as hungrier in the home appeared in feeding-grounds earlier than repleter flies, which remained in the home until they in turn became hungry. In the earlier experiment, carried out with *G. morsitans* in 1929, a result was obtained showing that hungrier flies actually did precede repleter flies from the home to the feeding-ground, but the figures did not appear to show that repleter flies remained any longer in the home than did hungrier individuals. The second experiment, done with *G. swynnertoni* in 1930, gave satisfactory results on both points. In a third experiment, on *G. swynnertoni* in July and August 1931, the following results were obtained.

1. Flies marked in the home and recaptured in the home.

Stage	Description	Number of days from marking to recapture								
		1	2	3	4	5	6	7	More	
I	Gorged	8	4	1	3	0	1	0	0	
II	Replete	27	13	3	7	6	9	3	16	
III	Intermediate	17	6	7	8	8	6	2	12	
IV & Y	Hungry and young, including females	11	5	3	1	1	2	1	8	

2. Flies marked in the home and recaptured in the feeding-ground.

Stage	Description	Number of days from marking to recapture								
		1	2	3	4	5	6	7	More	
I	Gorged	1	0	4	1	2	0	0	2	
II	Replete	9	9	4	1	2	2	3	5	
III	Intermediate	46	13	6	5	6	2	1	3	
IV & Y	Hungry and young, including females	51	8	3	1	9	3	2	8	

* In the 1931 paper there was an error in the last table on page 178, line 1, column 2, where the value -0.30 should have been $-\infty$. This does not of course affect the important last line of the table. Natural logarithms might have been preferable here, but the actual heights of the peaks on the periodic curves were not important.

Treating these two sets of figures in the same way as the earlier ones (1930 and 1931), we have :—

Place of marking	Place of recapture	Stage	Condition	First 3 days	Afterwards	Ratio
Home	Feeding-ground	III-IV & Y	Hungrier	127	40	3.2 : 1
..	..	I-II	Repleter	27	18	1.5 : 1
Home	Home	III-IV & Y	Hungrier	49	49	1.0 : 1
..	..	I-II	Repleter	56	45	1.2 : 1

As in the first experiment (*G. morsitans*), all the figures are in favour of the feeding-ground theory, suggesting that hungrier flies arrive earlier in the feeding-grounds and that repleter flies remain longer in the home, but the difference in the home-to-home recaptures again is insignificant. The reason seems to be that hungrier flies, whether they remain in the home or proceed to the feeding-ground, are more likely to be recaptured on the day following marking than are the repleter flies. This would tend to exaggerate the apparent difference of time of arrival in the feeding-ground, and to reduce the apparent difference of time of remaining in the home, as between hungrier and repleter flies. In the 1930 experiment (*G. swynnertoni*) significant results were nevertheless obtained under both heads.

In the experiment just described the home was represented by typical "hard-pan" supporting the usual replete fly population with Mean Hunger Stage 3.08. The feeding-ground was represented by a road and firebreak separated from the home by a game-proof fence, and by two-thirds of a mile of bush.

In another experiment, carried out in the same site in November and December 1930 (the break of the rains), the figures, although small, also supported the theory. The results of this experiment are given below.

Stage	Description	1. Home to home			2. Home to feeding-ground		
		First 3 days	Afterwards	Ratio	First 3 days	Afterwards	Ratio
I	Gorged	3	3	1 : 1.0	0	1	1 : ∞
II	Replete	4	3	1 : 0.8	6	8	1 : 1.3
III	Intermediate	8	10	1 : 1.4	17	14	1 : 0.8
IV & Y	Hungry and young, including females	1	2	1 : 2.0	15	4	1 : 0.3

These results, although small, are in harmony with the hypothesis, with the exception of the first line on the left-hand side.

To sum up, individual experiments show certain discrepancies, but on the evidence it can now be said that hungrier flies do precede repleter individuals from the home to the feeding-ground, no experiment having given a contrary result. That is, every few days, with the onset of hunger, individual flies proceed from the home to the feeding-ground; they remain for a short time, and on obtaining food return to the home, at the same time as their at first repleter companions are moving under the stimulus of hunger from the home to the feeding-ground.

It should be noted that these experiments do not tell us what proportion of flies in every batch which is becoming hungry in the home actually do visit the feeding-ground, and what proportion find food fortuitously in the home. The more rapid the onset of hunger, the less are the chances of finding food in the home before real hunger drives the fly into the feeding-ground. It will be shown in a subsequent section that at certain times of year the fly becomes hungry more slowly, and that at these times hungry flies are seldom met with and relatively few flies are found in the feeding-grounds. It is supposed that flies at these times meet food usually in the home while still in the intermediate stage of hunger (stage III).

It might be argued against the validity of the experiments just discussed that the hungry flies found in feeding-grounds represented those which had followed game animals, which admittedly pass much through feeding-grounds, and had failed to obtain food from their hosts. Further, it could be pointed out that it is the hungry flies which are the most tenacious followers, which fact might account for the high hunger values obtained from feeding-grounds. Against this possible objection, in the two experiments just described the home was separated from the feeding-ground by a game-proof fence; and, secondly, evidence of very considerable independent movement of tsetse-flies, especially when urged by hunger, is available. This evidence will now be discussed.

In a previous paper (1930) "catching-out" experiments were described, in which a stationary party at the heart of a feeding-ground continued to take a more or less steady trickle of arriving flies (*G. morsitans*) for periods up to 3 hours. A similar experiment was performed in Shinyanga in August 1930, lasting for 9½ hours. Flies arrived more or less steadily (following the initial high catch) for the whole of the period, except a falling-off from about mid-day until 3.30 p.m., after which time numbers rose again towards evening. The site was a feeding-ground of *G. swynnertoni* which had formed the subject of the experiment described in 1931, and which included a road. Two natives passed by along the road during the progress of the "catching-out," and as rises in numbers of flies at these times seemed to be associated with their passing, the times of their passage are marked with asterisks in the following series.

The flies taken in successive half-hours from 8.06 a.m. to 5.36 p.m. were as follows : 53, 29, 9, 13, 14, 12, 8, 18*, 8*, 8, 3, 3, 2, 1, 3, 8, 10, 4, 9.

After the passage of the two men, the drift of flies was low from the 11th to the 16th half-hour period, after which they rose again to a fairly high level. The conclusion is irresistible that flies taken in this experiment were really arriving of their own accord, and were not merely being cleared off gradually from an aggregation already existing on the spot at the start of the experiment. It is interesting to note that 7 of the flies taken had been marked in the adjacent bush from 2 to 15 days previously. The Mean Hunger Stage of all flies together marked in this bush during the previous 6 weeks had been under 3.0, whereas the M.H.S. of flies caught in this experiment in the feeding ground was 3.61. These facts suggest that many of the flies taken were emerging from the bush of their own accord, as distinct from being brought on animals, under the stimulus of hunger.

In the two experiments described above, in which *G. swynnertoni* traversed two-thirds of a mile of bush and a game fence in order to reach a feeding-ground, 2,792 flies in all were marked in the bush. Of these, no fewer than 63, or about 2 per cent., were recaptured in the feeding-ground on the same days as they respectively were marked. In addition, 7 flies, also on the days of marking, passed the game fence and feeding-ground and a ragged clearing beyond to be recaptured in the bush on the far side. Of these flies 2 travelled over 2 miles in a maximum time of 3 hours, in the absence of human traffic from the site of release to that of recapture, and during the hot hours of the day when game would not be moving about. Nearly all of the flies mentioned were in the intermediate or hungry stages, or were young.

The evidence seems conclusive that flies when stimulated by hunger will travel considerable distances independently of carriage on man or game. As one critic of work of this kind has mentioned that wind was not taken into account, it may be as well to state that these flights were made against the prevailing wind.

(The above cases concern movements of flies under known conditions. Over longer periods flies have been known to travel much greater distances through the fly-belt. One example of *G. morsitans* was recaptured 18 miles from its release point.)

V. Hunger and Physical Factors.

A. Empirical Considerations and General Observations.

The consensus of opinion seems to be that tsetse-flies do not drink water in nature. In any case many individuals of *Glossina morsitans* would not have access to water during a greater part of the year. With this in mind the writer made the suggestion that tsetse-flies ought to feel hunger and thirst as one sensation, and that their need for blood ought to rise with rising evaporation-rate. At the same time it was suggested that the apparent abundance of flies, in feeding-grounds especially, at times of high evaporation-rate might be attributable to this cause.

The effect of shortening the hunger cycle would be to cause the fly to live more quickly, to die more quickly, and, granted a food supply adequate to its increased needs, to reproduce more quickly. The effect of a shortened hunger cycle would not, therefore, be of itself necessarily adverse to the tsetse. But, unless the food supply remained more than sufficiently abundant, the shortened hunger cycle would decrease the chances of the fly's meeting with food fortuitously while still relatively well-fed, and so would affect the rate of reproduction. Some flies also might die from starvation.

The writer has described (1930) some of the results of his own and Mr. Burt's work on *G. morsitans* in Sambala in 1929, showing that with a rising evaporation-rate was associated a rise in hunger of fly and female percentage, and a rise in fly numbers taken in feeding-grounds as compared with fly numbers taken in the home. This was not explicable by a decrease in the food supply, as a rise in the numbers of host animals was recorded at this time.

Since then the writer and subsequently Mr. Lloyd have found similar behaviour characteristic of *G. swynnertoni* in Shinyanga. This species seems scarcely to become hungry at all during seasons when the evaporation-rate is low, and at these times the feeding-grounds are almost evacuated. Again, it is apparent that a decrease in the food supply during the drier seasons is not the cause, since at these times game is more abundant in the area studied than during the damp months.

B. The Hunger Cycle.

In the account (1931) of an experiment carried out on *G. swynnertoni* in 1930 it was shown that the hunger cycle at that time and place occupied probably 5 days. That is to say, the average fly would go 5 days from feed to feed.

In the following year a similar experiment on *G. swynnertoni* was performed in the same months, July and August, and a similar result was obtained. Perhaps the best way of showing this is as follows. We assume that the four hunger stages are of approximately equal duration. Then all the recaptured flies can be divided into four groups, namely:—

1. Flies passing through 1 stage, *i.e.*, I to II, II to III, III to IV, or IV to I.
2. Flies passing through 2 stages, *i.e.*, I to III, II to IV, III to I, or IV to II.
3. Flies passing through 3 stages, *i.e.*, I to IV, II to I, III to II, or IV to III.
4. Flies recaptured in the same stage as that in which they were marked.

The fourth group will be compound, being composed of flies which have not become measurably hungrier since marking, giving high figures in the first day or two, and flies which since marking have passed through the whole hunger cycle, giving high figures after a few days. The results of the 1931 experiment treated in this way appear as follows:—

Stages passed	Number of days from marking to recapture						
	1	2	3	4	5	6	7
1	51	15	10	8	6	10	6
2	3	11	7	4	0	0	0
3	2	5	15	9	4	5	2
4	79	10	6	13	14	7	3

In the first three groups the peaks on the falling curves occur on days 1 and 6, on days 2 and 3, and on days 3 and 4, respectively. This implies that flies tend to move on 1 stage in 1 day, and again 5 days later; 2 stages are passed through in 2 or 3 days, and 3 stages in 3 or 4 days. In the fourth group the high figure on the first day represents flies which have not passed out of the stage in which they were marked; the subsequent peak on the 4th and 5th days indicates that the whole cycle is completed in 4 or 5 days.

It should be added that the reason for the scarceness of flies in the second and third groups in the table, which may account for the absence of a rise on day 7 in the second line, is that the commonest stages originally marked were II and III, owing to the comparative inactivity of flies in stage I, and to the fact that flies in stage IV have mostly left already for the feeding-ground, where no marking took place. The commonest classes of recaptures, therefore, are flies released in stage II and recaptured in stage II or stage III, and flies released in stage III and recaptured in that stage.

The experiment of the year before treated in this way gives a less satisfactory result; however, flies in the important fourth group show a peak on the fifth day. Thus:—

Stages passed	Number of days from marking to recapture						
	1	2	3	4	5	6	7
1	58	12	4	2	4	3	1
2	3	3	4	3	0	0	0
3	1	2	6	5	3	4	3
4	80	4	3	6	12	7	3

The 1929 experiment on *G. morsitans* can be divided into two periods. In July the weather was cold and the evaporation-rate low; in August it was warmer and the evaporation-rate considerably higher. In July, when it is supposed that the hunger cycle was longer, no periodicity can be detected in a table constructed as

above. But the recaptures in August suggest a periodicity of about 4 days. This is apparent in the following table, which shows recaptures in the first 9 days after marking.

Apart from the usual high figure on day 1 in the last line, representing flies which have not changed their hunger stage since marking, this line shows peaks on days 4 and 8, suggesting that a hunger cycle of 4 days may have been obtaining at this time.

Stages passed	Number of days from marking to recapture								
	1	2	3	4	5	6	7	8	9
1	11	8	5	8	3	1	2	1	1
2	3	4	1	4	1	0	1	3	1
3	1	3	1	2	2	1	0	2	1
4	30	10	5	12	3	2	4	9	3

In the two accounts (1930 and 1931) of the earlier experiments, numerous cases of flies several times recaptured were considered. In the later experiment carried out on *G. swynnertoni* in 1931 further examples were obtained, although not many throw light on the duration of the hunger cycle. The table (p. 463) shows the stages of hunger reached on successive days of capture by all the flies that were of interest in this connection.

Among the 31 cases cited, Nos. 12, 16, 25, 28, 43, 45, 47, 54, 60, 62, 64, 84, and 85 suggest a hunger cycle of from 4 to 5 days; a cycle of from 5 to 6 days is suggested by Nos. 30, 37, 67 and 79, as well as by Nos. 43, 54, 60, 62, 64 and 85 already mentioned. Cases not suggesting hunger cycles of such durations are Nos. 29, 31, 42, 44, 53, 76, 78, 82 and 86. Nos. 48, 54, 60, 66 and 70 show that sometimes at least flies pass through about 1 stage in 1 day.

From the table, then, we can conclude that the hunger cycle probably occupies a little less than 5 days, and that in a hunger cycle of 5 days the successive stages normally passed through would probably be as follows:—

Day	1	2	3	4	5
Stage	I	II	III	III	IV

These results agree well with those obtained previously by this and other methods. It will now be shown that this cycle agrees also fairly well with results obtained in the rains by a somewhat different method.

It has been stated already that the hunger cycle is believed to vary with the season of the year. When the cycle is long, many flies never reach the hungry stage, and it is not possible to determine the cycle in the same way as when it is short. A more oblique method of approach is therefore necessary.

[illegible]

In April 1932, the rainy season, an experiment on *G. morsitans* was carried out in Eastern Singida, for which the following method was adopted. Flies were divided into three categories, namely, early, typical, and late, in every stage of hunger. These sub-stages were found recognisable in practice, only three cases of certainly wrong diagnosis being discovered. In two of these, flies recorded as marked in stage III typical were recaptured in stage III early on the following day, and in one case a fly marked as late stage III was retaken in typical stage III on the day following. Out of 154 flies recaptured within 3 days of marking there were no other obvious cases of wrong diagnosis. The three cases mentioned have been omitted from the table (p. 465). In this table are shown the numbers of flies which reached successive sub-stages in respectively 1, 2, and 3 days after the original marking. The mean sub-stage reached in every case was then worked out for every day of the three. Thus it was found that a fly marked originally as III early, for example, tended to be in sub-stage III early or III typical on the day following, III typical on the second day, and IV early on the third. The recaptures of flies marked as originally in stage I were too few to use, and have therefore been omitted from the table.

While not all the mean values obtained are significantly different from each other, there is sufficient difference to show that the hunger cycle is at least longer than it was supposed to be in the dry season.

Six flies which had fed again since marking are of course not included in the table.

The theoretical hunger cycle which most closely fits the results (shown in the table) is as follows, allowing a day for stage I.

Day	Stage
1	I
2	II early
3	II late
4	III early
5	III early to typical
6	III typical
7	III typical to late
8	III late to IV early
9	IV early
10	IV early or IV typical

Examination of all cases of flies recaught in a stage earlier than that in which they were marked suggests, assuming this table to be approximately correct, that flies normally feed in stage III late at this time of year. If this assumption is correct, we should expect to find an actual cycle of from 7 to 8 days, since it is on these days that stage III late occurs in the table. To test this, we revert to the method used on page 460. In this case it will be best to recognise 6 sub-stages, namely I, II early, II typical and late, III early, III typical, and III late including such few

Released stage	Recaptured stage	1 Day after	2 Days after	3 Days after
II early	II typical	3	1	
"	II late	5	1	1
"	III early	1	1	
"	III typical	1	2	
"	III late	1		
"	<i>Means :</i>	II late	III early	—
II typical	II late	4	1	1
"	III early	5	3	2
"	III typical	2	2	3
"	III late	1	1	
"	<i>Means :</i>	III early	III early to typical	III early
II late	II late	3		
"	III early	6	1	
"	III typical	2	1	1
"	III late	1	1	1
"	<i>Means :</i>	III early	III typical	III typical to late
III early	III early	11	2	
"	III typical	11	3	
"	III late	1	3	2
"	IV early			1
"	IV typical			1
"	<i>Means :</i>	III early to typical	III typical	IV early
III typical	III typical	7	1	
"	III late	4	5	1
"	IV early	1	1	
"	IV typical		1	1
"	<i>Means :</i>	III typical to late	III late	IV early
III late	III late	3		
"	IV early	1	3	1
"	<i>Means :</i>	III late	—	—
IV early	IV early	2	1	
"	IV typical	2		
"	<i>Means :</i>	IV early to typical	—	—

flies as are in stage IV. (Owing to the practical disappearance of stage IV in the field at this season, we cannot use the 4-stage grouping as before.) This arrangement will give 6 groups, and the following table :—

Stages passed	Number of days from marking to recapture											
	1	2	3	4	5	6	7	8	9	10	11	12
1	36	15	3		3	1	1		2	1		4
2	7	5	10	2	1	1		2			2	1
3	5	5	4	1	2	1			3	1		
4			3	5	2	2	1	2		3		3
5					3		2	3	1	1		2
6	28	3	1			4	1	2	1	1		3

This table clearly agrees very well with the hypothesis, since it would appear to indicate a hunger cycle of about 8 days, the figures mostly coming down into the last line about the 8th day, and the general slope in the other lines tending to about the same point. It should have been noted that the flies in sub-stage II typical could equally well have been grouped with those in sub-stage II early instead of with sub-stage II late. This grouping would have made no appreciable difference to the table.

From these several experiments, then, it is concluded that the hunger cycle of *G. swynnertoni* in Shinyanga in July and August is about 5 days; and that the hunger cycle of *G. morsitans* may be about 4 days in the height of the dry season, and is about 7 or 8 days in the rains. This rains cycle of 7 or 8 days occurs when flies are feeding, on the average, in about late stage III; if they went on to stage IV as in the dry season the hunger cycle in the rains would occupy 10 days or more.

It may be added that in the wet season the writer has kept captive *G. morsitans* for as long as 15 days from feed to feed.

C. The Physical Causes of Hunger.

1. Objects, Site, and Methods of Investigation.

Subsequent to the closing of Mr. Burt's and the writer's work, already referred to, at Sambala in 1929, no work was done on this subject until October 1931, when the writer began observations at Masiliwa which were continued until August 1932. Following the indications given by the Sambala work, it was hoped to obtain decisive proofs as to whether greater hunger of flies was associated through the year with greater severity of the physical conditions, notwithstanding the compensating factor of an influx and concentration of host animals occurring at the height of the dry season. Secondary objects were to re-prove that such increases in hunger were associated with an increased proportion of flies found in the feeding-grounds, and with other entomological effects, and to determine which of the physical factors best could be correlated with changes in the hunger condition of the fly.

Masiliwa is a native settlement situated about 20 miles west of Sambala in the Kondoa-Singida fly-belt in the Central Province of Tanganyika Territory. The vegetation is in general similar to that described for Sambala (1930). The altitude

is about 4,900 ft. (Obst, 1923). Climate and seasons did not differ greatly from those described for Sambala. Monthly figures for 1931-32 are given in the following table :—

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Inches of rainfall ...	1.76	2.22	6.34	2.85	1.47	0.00	0.00	0.00	0.00	0.00	0.20	8.91
Maximum temp. (F.)	86	86	88	80	78	78	81	84	86	86	89	—
Minimum temp. (F.) ...	52	52	59	55	50	46	40	46	48	49	51	—

The temperature figures are the extreme maxima and minima for every month, not the mean values. They are incomplete for February, September, October, and December. In the figures for January, March, and August some figures from the end or beginning of preceding and following months are included. The rainfall figures are complete for the year, the total fall amounting to 23.75 inches. The chief differences from the climate as described for Sambala were in the "short dry season," which this year was broken by light rain amounting to 2.09 inches from 28th January to 9th February inclusive, and in the contraction of the late dry season to a period of about 10 days only at the end of November.

Fly catches were carried out about 2 miles east of the Station. The feeding-ground of the fly was represented by part of a seasonal swamp adjoining woodland of *Berlinia-Brachystegia*. It included permanent pools frequented in the dry season by zebra, greater kudu, Coke's hartebeest, duiker, dikdik, wart-hog, and rhinoceros. Animals were never very abundant. Two blocks of the adjacent woodland represented the home of the fly. The nearer of these (i) to the feeding-ground presented certain features (flies of very various hunger conditions, and a large percentage of gorged flies) which suggested that it formed an entomological transition area, and it has been omitted from the correlation figures used. The following table shows that flies in this section are slightly hungrier than in the home proper (ii).

Type	Period	M.H.S.	Females %	Young fly %	Total fly
Feeding-ground ...	Oct.-Nov.	3.51	29.0	11.8	466
	Dec.-Apr.	3.35	16.4	14.1	427
	July-Aug.	3.42	26.0	8.3	312
Home (i) ...	Oct.-Nov.	2.89	12.8	7.5	187
	Dec.-Apr.	2.80	10.7	5.3	150
	July-Aug.	3.00	14.5	9.1	110
Home (ii) ...	Oct.-Nov.	2.76	9.4	5.2	479
	Dec.-Apr.	2.72	5.5	5.3	638
	July-Aug.	2.80	7.5	6.6	347

It will be seen that in the higher values obtained for hunger, female percentage, and young fly percentage, the feeding-ground shows the normal characteristics of such places.

The procedure of fly sampling was as follows. The catching party caught off following flies before entering the feeding-ground, and then proceeded at a rapid

pace to the site near the pools about 200 yards from the scene of the preliminary catch-off. Here two standing catches 70 yards apart were made in turn, each occupying 10 minutes. The party then proceeded to the first (transitional) part of the woodland, where, after catching off following flies, ten halts were made at minute intervals 20 yards apart. In the second section of the woodland (the home proper) following flies were caught off as usual, but the stops were at 50-yard intervals in a total traverse of 800 yards. This section included an intermediate sub-section of more thicketed woodland, where fewer flies were caught. This catch in the home proper occupied about 20 minutes. The three catches in feeding-ground, transition, and home together occupied about an hour, from 4.0 to 5.0 p.m.

Temperature, relative humidity, and saturation deficit were taken from whirl psychrometer readings made immediately after the catch in the feeding-ground, about 4.25 p.m. The evaporation-rate was read at 8.0 a.m. on the morning following the catch, the atmometer (white bulb at 6 inches) being at Masiliwa Station. It had been supposed that evaporation-rate would give the closest correlation with hunger in the fly, as this complex factor gives in many ways the best picture of the severity of the physical conditions through the day. However, evaporation-rate is to some extent an arbitrary measure of atmospheric conditions, representing as it does only the amount of water lost from the instrument used. According to the choice of instrument, the several component factors (temperature of the air, solar radiation, relative humidity, and wind force) vary relatively to each other in their effect on the evaporation-rate. Actually, the correlation between hunger of fly and evaporation-rate proved to be relatively weak, better correlations with relative humidity and saturation deficit being obtained. These two factors are to some extent an absolute measure of atmospheric conditions, and, provided they are taken at about the driest time of day, give a good indication of the severity of the conditions during the preceding 24 hours.

2. *Factors Working against Correlation.*

If it be true that fly is hungriest when the physical conditions are most severe, which occurs (in this area) when host animals are most numerous in the feeding-grounds, and most easily seen owing to absence of foliage, then we have at once two opposing factors acting on the hunger of the fly. Further, since the relative value to the fly of a dikdik or of a rhinoceros is not known, or of one zebra as opposed to four, a partial correlation with the game factor eliminated is difficult to obtain.

Moreover, the hunger values obtained are determined partly by the true state of hunger in the fly and partly by activity effects. Such variations as are found in the hunger values obtained in the home of the fly are believed to be attributable very largely to factors causing periodic activation of flies in stage II. A more serious effect, suspected from casual observations and from empirical considerations before this investigation was begun, is that on very cold, damp days unfavourable to fly activity hungry flies only will consent to appear to the catchers. This effect may account in part for the raised percentage of female flies observed by Nash (1930) in the early mornings at the colder times of year. At Masiliwa, inactivation of all but hungry flies, and of the majority of those also, was found to occur at temperatures below 70°F. Partial effects of the same kind may have accounted for hungrier estimates found sometimes at temperatures up to 77°F.

3. *Situations giving Correlation.*

In the table on page 467 it will be observed that there is but slight variation in the hunger values from the home of the fly from season to season, but that in the feeding-ground there is considerable variation. This is supposed to be because flies at the onset of hunger leave the home for the feeding-ground, and is therefore in accordance with the feeding-ground theory. The very slightly higher hunger values obtained in the home at the drier times of year may be ascribed to a slight

lag in movement of fly to the feeding-grounds when the shorter hunger cycle catches the fly, so to speak, unawares. Accordingly all correlations should be sought either in the feeding-ground alone or in the feeding-ground and home combined. The first method is generally the more desirable, since results are comparable from place to place. The second method tends to counteract extreme activity effects in the feeding-grounds, but the values obtained, while comparable from day to day, are arbitrary in that they depend on the relative numbers of flies taken in the home and in the feeding-ground in the sites chosen for the observations. Figures are therefore taken from the feeding-ground only to give the correlations about to be described.

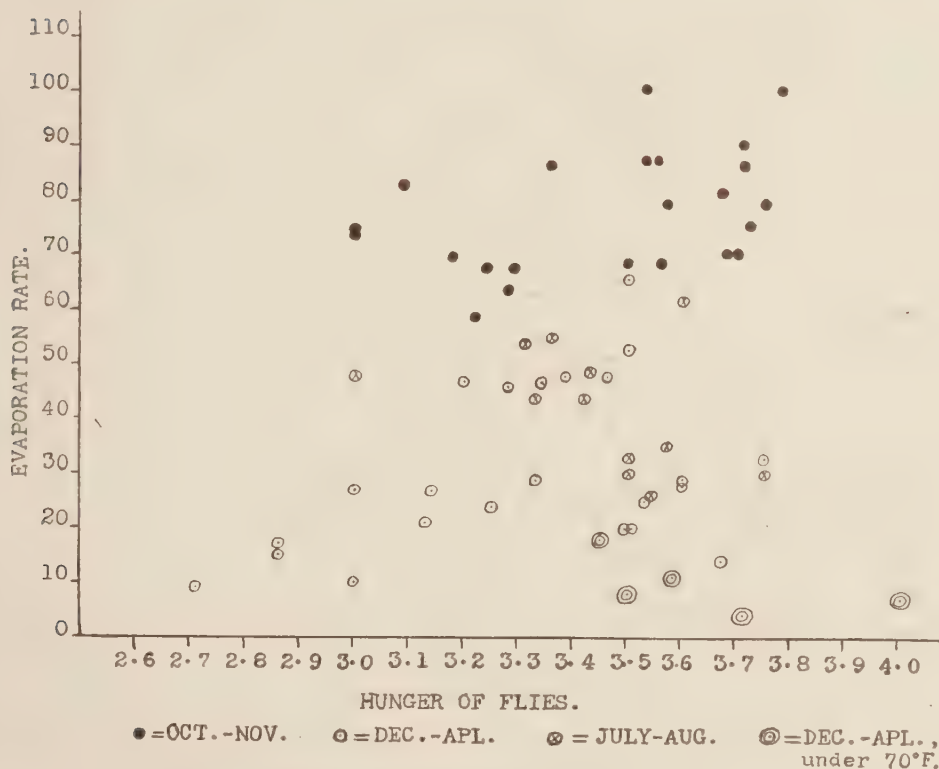


Fig. 1. Correlation between hunger and evaporation-rate.

4. Correlations obtained.

Correlation between hunger and evaporation-rate is fairly good (fig. 1) when the evaporation-rate rises above 40 ccs. per day. (These readings are not corrected for the instrument used, and are too high.) Below 40 ccs. the readings are very various. Significant but not strong correlation with hunger is obtained if the 5 points taken from days with temperature under 70°F. are eliminated. A barely significant correlation is obtained for the 23 mid dry season points taken alone, and a stronger correlation for the 25 days on which the total catch of flies exceeded 20. However, the agreement of hunger with evaporation-rate is clearly unsatisfactory.

The correlation of hunger with relative humidity (fig. 2) shows a very much better agreement. It is apparent that, with the exception of the 5 low-temperature

days, the aberrant points on the evaporation-hunger graph referred to dry days with low evaporation. If the 5 low-temperature days are included in the humidity-hunger correlation, this becomes insignificant, whereas without them it is strong. Evidently these 5 points represent the activity effect mentioned above, according to which hungry flies alone will attack when conditions are unfavourable. If the wet bulb depression is used instead of relative humidity the correlation is slightly, not significantly, better.

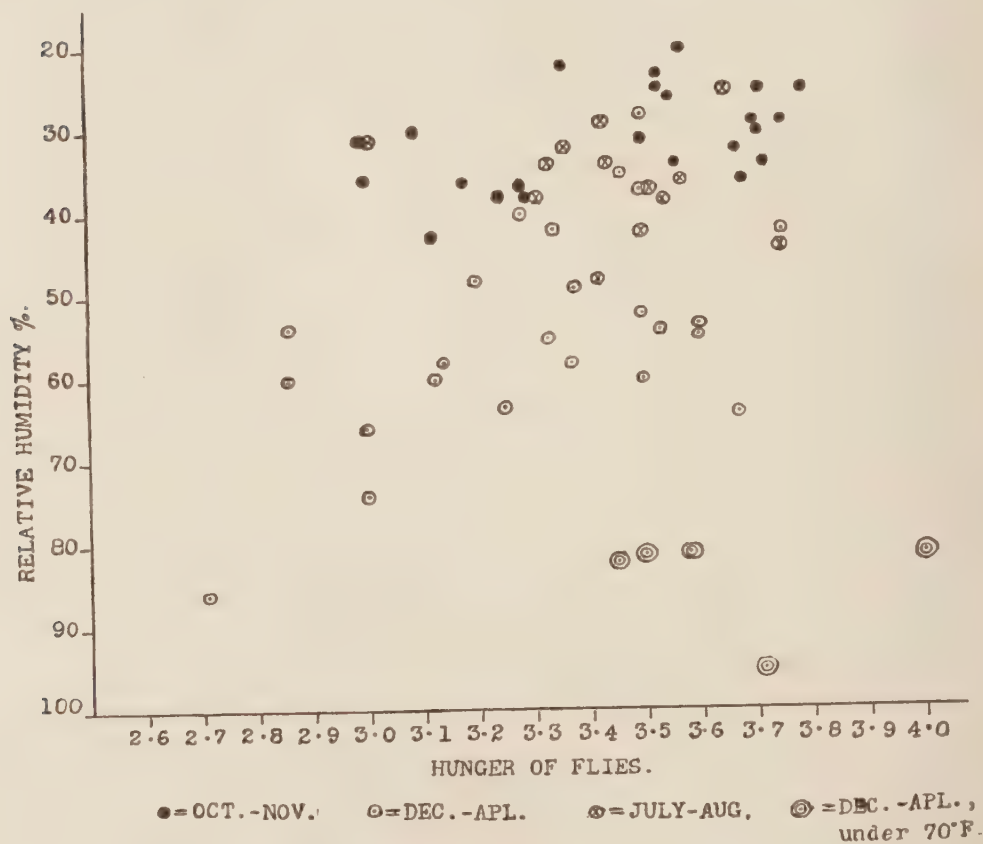


Fig. 2. Correlation of hunger with relative humidity.

Correlation of hunger with saturation deficit (fig. 3) is rather less strong than the correlation of hunger with relative humidity. But the slope of the mid-dry season points is more nearly the same as that of the remainder than in the humidity-hunger graph. This point will be referred to again in the next section.

In case anyone should have doubts about the possibility or reliability of assigning flies to different hunger stages on their external appearance, a graph (fig. 4) is given showing that a correlation not significantly different from that shown in fig. 3 is obtained if hunger of flies is judged from their behaviour instead of from the usual estimate founded on their hunger stages.

The picture of the correlation of hunger with wet bulb depression is intermediate between the hunger-relative humidity and hunger-saturation deficit pictures. The

last resembles the hunger-temperature picture, tending towards the hunger-evaporation type. This is what would be expected, since the saturation deficit graphed against the temperature gives practically a straight line, whereas the relative humidity graphed against the temperature gives a less close agreement, especially in the early dry season when temperatures tend to be lower.

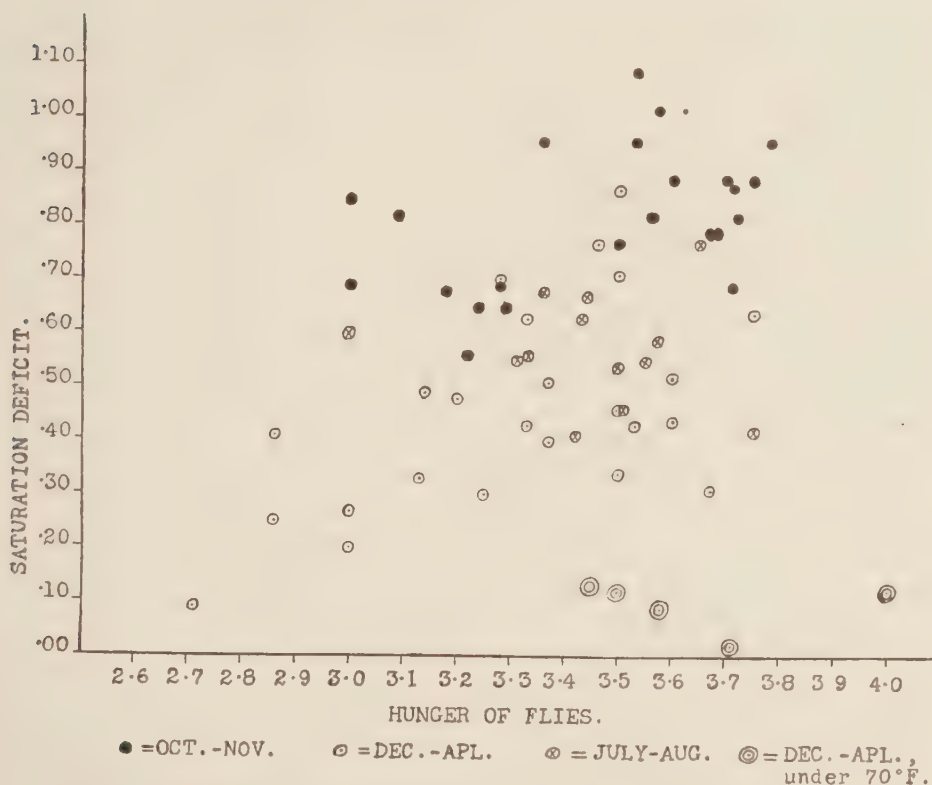


Fig. 3. Correlation of hunger with saturation deficit (judged by external appearance).

Since the proportion of flies using feeding-grounds ought to be greater when flies are hungrier, it follows that this proportion ought to be associated also with the factor causing hunger. In the following table are grouped in terms of the relative humidity the hunger values of flies in the feeding-ground and the proportions of the numbers of flies in the feeding-ground to numbers in the home. The numbers of animals seen, or spoors of the same day, in the feeding-ground are given also.

The hunger values show good agreement with the proportion of flies in the feeding-ground. When hunger is greater, more, proportionately, are found in the feeding-ground, both sets of values being correlated with relative humidity. The figures in the last column, including as they do 5 days when the temperature was below 70°F., give artificially higher hunger values, with small catches of flies both in the feeding-ground and in the home, but a high proportion of flies in the feeding-ground. In the first 5 columns the mean catches of flies in the home are fairly constant, but the mean catches in the feeding-ground fall from low to high relative humidities. In column 2 the hunger value and the proportion of flies in the feeding-ground are

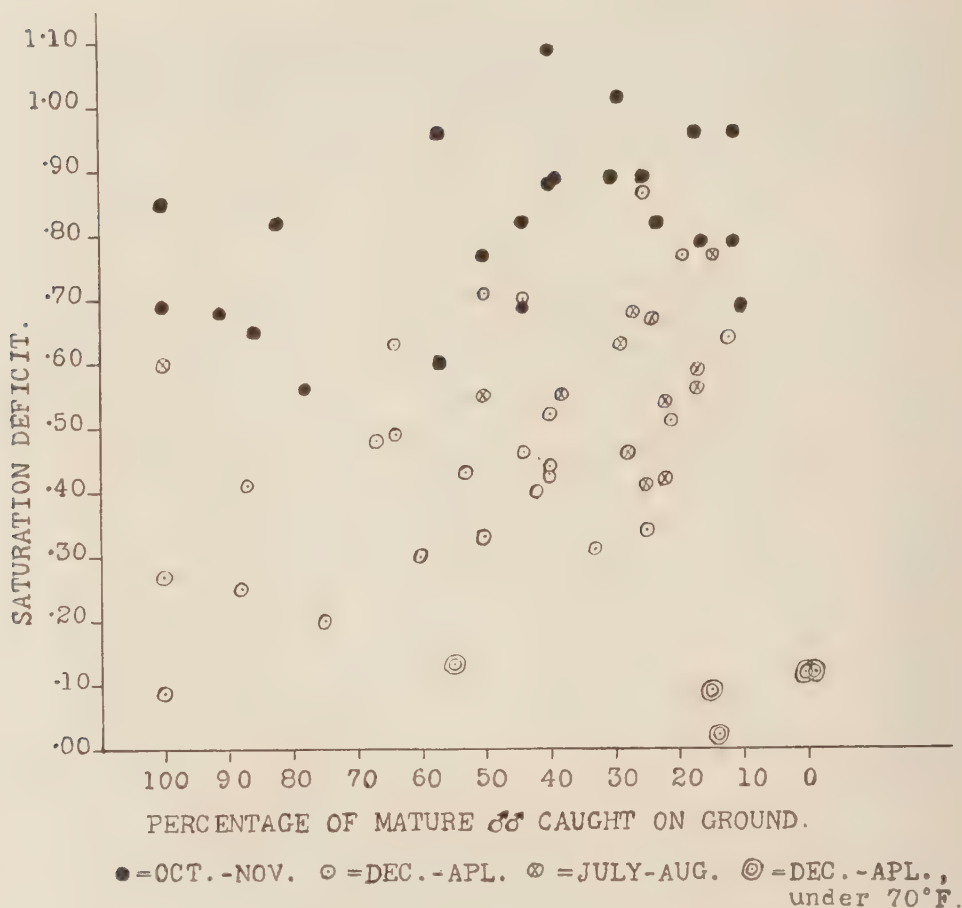


Fig. 4. Correlation of hunger with saturation deficit (judged by behaviour).

both rather low ; this point will be noticed in the next section. The host animals, as already noted, are most numerous when fly is most hungry and with the lowest relative humidity. The table as a whole agrees well with the feeding-ground theory.

Relative humidity %	20-29	30-39	40-49	50-59	60-69	70 & over
Mean daily catch in F.G. ...	25.9	22.2	21.9	14.1	11.3	11.4
Mean daily catch in home ...	23.75	25.9	25.3	24.25	23.5	9.3
Proportion in feeding-ground ...	1.09	0.86	0.86	0.58	0.48	1.23
Hunger in feeding-ground ...	3.59	3.41	3.42	3.35	3.22	3.40
Host animals per day in F.G. ...	1.58	0.96	0.56	0.125	0.33	0.14
Number of readings ...	12	21	9	8	6	7

(Note.—The total number of observations in the table is 2 less than on the relative humidity graph, because on 2 days there was no catch in the home. On the evaporation

graph there are also 2 readings missing, as there was no evaporation reading on those days. The total number of observations each month was: October 9, November 14, December 3, January 9, February 9, April 8, July 9, August 3.)

5. General Conclusion.

Good correlation of hunger with relative humidity, wet bulb depression, and saturation deficit is obtained, provided that days are excepted on which the temperature at the time of the reading is below 70°F., when fly activity is reduced and hungry flies only are seen. Correlation with evaporation is moderate only, suggesting that it occurs only indirectly through the association of evaporation-rate with relative humidity and saturation deficit. The proportion of flies in feeding-grounds can be correlated with hunger and with relative humidity. As suggested at the start of this investigation, fly probably feels hunger and thirst as one sensation.

(Note.—According to Mr. Chorley, *G. palpalis* is hungrier in the wet season, and the writer saw for himself that during the dry weather on an island on the east side of Lake Victoria very few hungry flies could be found, and that few flies were then being taken in traps where large catches had been made shortly before. This is the opposite of the behaviour of *G. morsitans*, *G. saynerloni*, and *G. pallidipes*, all of which become hungry in dry weather, when they are more readily trapped. The writer is unable to find any empirical reason for this anomalous behaviour of *G. palpalis*. It must be remembered that this species lives in a climate of relatively constant humidity. However, it is clear that more investigation of this matter is needed.)

VI. Hunger and the Game Factor.

This subject is so important, and the views of different workers upon it so conflicting, that the suspicion of prejudice now greets every new contribution. The writer will try to give evidence rather than views, but some general considerations must be set down first.

An insect dependent on a migratory food supply, and not itself migrating, might be expected to be hungrier at times when food was scarcer. Moreover, it happens in many parts of the country, that, at times of year when food is scarcer, not only is the food itself (in the country studied) not concentrated in recognisable sites, but the visibility within the woodland is greatly reduced by vegetable growth.

At the same time it has to be remembered that the number of flies which can feed off a single large animal is practically unlimited. In this important respect blood is different from other foods. All that is necessary is that host animals should be sufficiently abundant to ensure that the tsetse should be able to meet with them before hunger becomes so acute as to affect reproduction or to cause death from starvation. Given these conditions, an increase in the number of hosts will make no difference to the parasite. In this respect the tsetse is not an animal the increase of which is limited by its food supply. Broadly speaking, if food is adequate to support permanently a few tsetse it is adequate for any number. If food is absent, or inadequate for a large population of tsetse, then not even a few can exist. The wild game seem scarcely intolerant of attack by swarms of fly, while cattle introduced into a fly-belt for experimental purposes seem to acquire comparative indifference to the bites, long before any symptoms of trypanosomiasis appear. It is unlikely, therefore, that wild animals would be driven from a fly-belt by the persistent biting of the fly, however numerous.

Individual animals, for the same reasons, will be of more value to the fly if they are scattered through the bush than if aggregated into herds. As it happens, migratory animals are chiefly those that move in herds, so that their seasonal exodus is

of less importance to the tsetse than it might otherwise be. On the other hand many, as zebra and Coke's hartebeest, are markedly diurnal and therefore likely to be useful as a food supply.

In the account of the game movements at Sambala (1930) it was shown that such migratory animals as eland, Coke's hartebeest, zebra, and ostrich were most numerous in the tsetse-infested bush during the mid and late dry seasons, and sometimes in the short dry season about February. Nash (1930) has similar observations on the movements of zebra and Coke's hartebeest, and in one year wildebeest and Grant's gazelle. All these animals were scarcest through the fly-belts as a whole (though in parts they remained) during the long rains. In Shinyanga the writer found the position to be similar; here the chief migratory animals were eland and impala.

But we have seen in the last section that fly is least hungry when the relative humidity is greatest, and this, as shown in the table on page 472, occurs at seasons when game is scarcest in the fly-infested bush. For the places studied it seems that the opinion expressed in 1930 is strongly confirmed, *that the abundance or scarcity of game as determined by their seasonal migrations is of almost no account to the tsetse beside the variation in physical conditions in its habitat.*

Dr. Nash has pointed out, further, that in the fly-belt studied by him the apparent density of fly (as noticed by the writer at Sambala also) was greater at the time when game was least abundant, and less at the time of the greatest influx of game. Thus again the time when host animals are scarcer seems to be the best time of year for the fly.

It has been mentioned in the last section that during the mid-dry season, when game animals were most numerous, the slope of the points on the hunger-relative humidity graph was different from their slope in the rainy season. On the hunger-saturation deficit graph the slope in the mid dry season was about the same as in the rains, but the mid-dry season points appear as if shifted back about 2 decimal places towards the left or repleter side of the graph. If this means anything, it is that the increase of game animals in the mid-dry season has sufficient effect to shift the hunger values by this amount, which, if real, is the utmost that can be claimed for the effect on the hunger of the fly of the number of game animals present in the area. (Animals per reading were 1.79 for the mid-dry season, and 0.43 for the rest.) This effect, as is apparent from a study of the hunger-relative humidity graph, accounts also for the rather low hunger value and low proportion of flies in the feeding-ground apparent in column 2 of the table on page 472.

It is not intended to imply that in all fly-belts the number of animals present has a negligible effect on the hunger or density of the tsetse. Conceivably in some fly-belts the tsetse is enabled to exist only through the presence of an inordinate number of host animals, any reduction in which would be fatal to the fly. Lloyd & Johnson (1927) refer to the long-grassed rainy season as being productive of starvation in the fly owing to the reduction in the number of its hosts and to the concealing effect of the rank vegetable growth. But no such condition has been observed by the writer. Thus in Uganda fly (*G. morsitans*) was found to be fairly replete towards the end of the first rains (November) in long-grassed country near the Nile, where the only animals seen in several days' observations were three bushbuck, two oribi, and a herd of Jackson's hartebeest. In other countries visited by the writer where the grass growth was fairly good, including Shinyanga (*G. swynnertoni*) and northern Nzege (*G. morsitans*), fly was replete at the seasons of maximum grass growth and, in Shinyanga at least, of minimum abundance of game. In such conditions, when the hunger cycle of *G. swynnertoni* may be prolonged to perhaps a fortnight or over, and that of *G. morsitans* may be hardly less, it is easy to believe that the fly can

depend on chance meetings to maintain its existence on a population of dikdik, duiker, and wart-hog, encountered in such short-grassed patches as are scattered through the fly-belt.

In an area visited by the writer near Kazikazi in the western part of Manyoni District in the Central Province of Tanganyika Territory, fly was living in an area practically enclosed by thicket, and communicating by a long, narrow outlet with the fly population outside. The larger animals consisted of one or two greater kudu, one or two giraffe, and one elephant and two rhinoceroses which paid casual visits. There was the usual population of such smaller animals as wart-hog, bush-pig, and dikdik, and at least one duiker. In this area (2½ square miles) it could not be supposed that the removal of these few larger animals would have any appreciable effect on the fly, which was fairly replete in June and August 1932. It is therefore likely that fly can continue to support itself on the non-migratory population of wart-hog, bush-pig, and dikdik, common to so many parts of tropical East Africa.

These points will be discussed further in the section on tsetse control.

VII. Hunger and Fly Concentrations.

In the present section some attempt will be made to suggest the homologies of different types of tsetse concentration. It is well known that in East Africa *Glossina palpalis* is restricted to what may be called linear concentrations, seasonal or permanent, around lake margins or alongside rivers and streams. This type of distribution may be compared to that of *G. morsitans* in the region of the great thickets of Central Tanganyika Territory (page 453), where the thickets may be compared to lakes and the fringing *Berlinia-Brachystegia* or *Terminalia-Combretum* woodland to the vegetation of the lake shore. Elephants and rhinoceroses in the thicket might also be compared to boats and hippopotami on the lake. Such linear concentration, dependent on very well defined boundaries of vegetational types, must be distinguished from the non-continuous concentration of *G. morsitans* described by Shircore (1914), Jack (1918), and Swynnerton (1921).

In this, the classical conception of tsetse concentration, flies assemble in the dry season about "vleis" or "mbugas," seasonal swamps with subsoil moisture, where trees are leafless for a shorter time, and game animals more frequent in the dry season, than in the fly-infested woodland round about. Swynnerton rightly urges that such seasonal, non-continuous concentration offers hope of fly control.

The explanations given for this seasonal concentration are two: the first, that fly is taking advantage of the less sharply deciduous conditions found in the vleis during the rigours of the dry season; the second, that the tsetse is gathering about the concentrated game.

The writer, working in Sambala and Masiliwa on this subject, has demonstrated, and Mr. Burt's observations both at Sambala and at Kazikazi have confirmed, that *Glossina morsitans* is taken in larger numbers in the vleis during the dry season, relative to the numbers taken in the surrounding *Berlinia-Brachystegia* woodland. There was, however, nothing approaching dry season evacuation of this vegetational type. It was suggested that apparent concentration in the vleis during the dry season represented nothing more than the more frequent visits paid by the now hungrier fly to its feeding-grounds at this time of year, and it was shown (1930) that flies were not evacuating the *Berlinia-Brachystegia* woodland, whether partly or not, in order to seek better shade conditions in the vleis.

At Kikori, in Eastern Kondo, Tanganyika Territory, Nash (1930) has described an almost opposite condition, where *G. morsitans* tends to evacuate *Combretum* savannah and small thickets in the dry season in favour of *Berlinia* or *Brachystegia microphylla* woodland. At these times also the apparent density of flies in the very large open vleis and plains that are a feature of the country about Kikori shows

relative and actual diminution. On this point Dr. Nash and the writer reached the following conclusions: In the open Kikori feeding-grounds large numbers of flies are not found in the centres, far from the sheltering woodland of the home, under the conditions of intense insolation prevalent at the height of the dry season. The fly hunts for its food along the *margin* of the feeding-ground. In Western Kondoia the fly live and breed in *Berlinia-Brachystegia* woodland almost surrounding the feeding-grounds or vleis, which typically are only some 75 or 100 yards in width, although they may be very long. At Kikori in Eastern Kondoia the fly also live and breed in the surrounding *Berlinia-Brachystegia* woods, but these woods are in contact with vleis that may be a mile across. If the observational fly-round cuts straight across the vlei, any concentration of fly around the *periphery* will not be noticeable at times when the *centre* is avoided by the fly. Thus the feeding-grounds at Kikori are considered to be similar in principle to those at Sambala and elsewhere in Western Kondoia, apparent differences being due to the fact that the Kikori feeding-grounds are larger.

Touching the tendency of the Kikori fly to abandon *Combretum* woodland for *Berlinia-Brachystegia* in the height of the dry season, Swynnerton in an unpublished note states that in Mossurise woodland of *Commiphora* was evacuated in favour of *Berlinia* before further dry season concentration took place.

About Sambala in Western Kondoia it is evident from the map (1930) that feeding-grounds, or "female centres" as they were called at first, are numerous, and that every area of *Berlinia-Brachystegia* woodland was well served with them, so that flies inhabiting the woodland were never distant more than a mile or two from their feeding-grounds, and were able throughout the year to maintain an even distribution within their home. But, in country where suitable vleis or other feeding-grounds are scarce in large areas of homogeneous woodland, as may happen in comparatively flat country, it might be expected that flies would move nearer to the feeding-grounds at times of year when frequent visits to them would be necessary to satisfy the increasing demands of appetite associated with a shortening hunger cycle.

Thus it is very likely that what was supposed by earlier workers to be concentration *within* the vleis or "dry season foci," for the sake of shade from more umbrageous trees, was really concentration *about* them when more frequent feeds became necessary. (Swynnerton, in another unpublished note, points out that in Mossurise concentration was not confined to the vleis, but included also a part of the *Berlinia-Brachystegia* woodland surrounding them.) In other words, where feeding-grounds are few, there will be found a condition approximating to dry season concentration round about them; where they are numerous, fly will remain evenly distributed between them, although in either case more flies relatively will be taken in them, or on their margins, at the height of the dry season.

Similarly the writer does not suppose that flies are, strictly, concentrating about the game in vleis in the dry season. Although the purpose is to find food, the instinct is evidently to seek first the vlei. Thus Dr. Nash has shown recently that in the wet season, when a water-hole was abandoned by game, the making of paths to it led to an increase of flies at the site, suggesting that it is the place rather than the animals that the hungry fly seeks first. It happens that when hunger in the fly is most intense game is most numerous about the vleis; but even in the rains, when game is not more numerous there than elsewhere, such hungry flies as there are still seek the vleis.

It may assist in the appreciation of the significance of the different types of tsetse concentration (*G. morsitans*) to take an analogy. The home of the fly may be regarded as a hotel in which the fly can feed for part of the year (the rainy season) and can obtain "accommodation." In the dry season food is difficult to obtain in the "hotel," although "accommodation" can still be had, and the fly when

hungry must frequently go out to feed in a "restaurant" (feeding-ground) in which it cannot live permanently. The "restaurants" are but little used at times of year when food is easily obtained in the "hotel," although a few flies continue to visit them from time to time. Perhaps it would be more strictly correct to say that, although food can at all seasons be obtained in the "hotel," the "service" is so slow that hungry flies are forced to visit "restaurants" instead, where the "service" is better. Thus at times of year when flies are more hungry the "restaurants" are better filled. The paths made to the water-holes by Dr. Nash may be compared to advertisements for a particular "restaurant," inducing flies to visit that one rather than another. At the edge of most fly-belts which border on open country unsuitable as a permanent habitat for fly, hungry individuals are found wandering in search of food far beyond what can properly be called a feeding-ground. These would correspond, in the analogy, to flies which had left the "hotel" to seek a "restaurant," and, not being "served" at once, had gone out again unfed to lose themselves outside the "town," and perhaps to die. Such areas are usually referred to by the writer as the *hungry fringe* of the fly-belt, and of course give high female percentages as well as high hunger values.

In the case of *G. swynnertoni*, the position is very much the same, except that this fly is able to feed in its "hotels" for a greater part of the year, perhaps all the year in some parts of the country.

While *G. morsitans* gives birth to its young in the "hotel," *G. palpalis* may choose for this purpose either the "hotel" or a corner of the "restaurant."

VIII. Hunger and Fly Control.

1. General.

Although it cannot be claimed that a study of variations in the local and seasonal states of hunger in tsetse-flies has led to any very promising suggestions for the elimination of these insects, the subject has bearings on almost every possible means of fly control. Thus should it be wished to ascertain the progress of some method of fly destruction by catches of flies taken at intervals in the affected area, a decrease in the catch will not be taken as a sign of success unless fly is at least as hungry afterwards as before, or unless hunger is no less than in a control area where no decrease in numbers has occurred. Or again, should it be intended to alter the vegetational conditions under which flies live, modification of the home and not of the feeding-ground would be more likely to succeed; should it be intended to trap hungry flies, clearly the best place for the traps will be the feeding-grounds. These and similar applications of results obtained will now be considered.

2. Direct Destruction of Adult Flies.

The work of Harris in Zululand (1930) on the trapping of *Glossina pallidipes* has focussed attention on this subject. The writer has experimented with various types of traps against this species and against *G. morsitans* and *G. swynnertoni* also. Undoubtedly traps can be made which will catch these flies well enough when they are sufficiently hungry. Unfortunately they are not hungry during the damp months of the year, and at these times large numbers of tsetse do not pass through the feeding-grounds where the traps are placed, nor will many flies enter the traps when they do see them at such times. It would appear, for example, that it is of little use to try to trap *G. morsitans* when the relative humidity is much above 40 per cent. *G. swynnertoni* in Shinyanga proved to become hungry only under conditions of great and maintained atmospheric severity and was even more difficult than *G. morsitans* to trap during a great part of the year. *G. pallidipes* in the same place was equally refractory, and in exactly the same way. Harris does not mention this difficulty in his account of fly-trapping, so that the writer does not know whether he has encountered it. *G. palpalis*, as stated on page 475, seems to be the opposite

of the other species, in that it is difficult to trap during the drier seasons. This is not so important on the Uganda side of Lake Victoria, where conditions are generally fairly humid; but on the east side a difficult season will be encountered if these findings are borne out by further investigation.

Similar considerations will apply to attempts to exterminate flies by hand-catching, or by any means which aim at the destruction of *attacking* tsetse.

3. *Destruction of the Food Supply.*

The history of the Transvaal seems to show that the removal of the tsetse's natural hosts results in the removal of the tsetse. (For a careful and critical summary of the history of the tsetse in various parts of South Africa, see Fuller, 1923.) In this connection it seems scarcely relevant to refer to the exceptional position described by Rutledge (1929) in the North Sudan, where domestic animals survived to feed the fly, or to parts of Tanganyika Territory where certain herds of cattle are immune or tolerant to the local strain of trypanosome. But we have seen in section VI that the hunger of fly seems to be scarcely affected by seasonal fluctuations in the numbers of game animals, and in fact that, owing to the overwhelmingly greater effect of the physical conditions of the atmosphere in determining the hunger of the tsetse, flies actually are hungriest and show lowest apparent density when their food supply is most abundant. Further it was shown to be extremely likely that tsetse could survive on such small animals as wart-hogs, bush-pigs, duikers, and dikdiks in the numbers in which these animals normally exist in many parts of Tanganyika Territory. As these animals, perhaps excepting the wart-hog, are difficult to exterminate, an experiment to determine the validity of this opinion would be very desirable, and should precede any measure of organised game destruction. Casual destruction without such an experiment is to be avoided, as it would certainly result in the disappearance from large areas of the easily-killed larger game animals, probably leaving the fly to maintain its existence on the smaller species named.

4. *Prevention of Fire.*

It was suggested that total suppression of the normal annual grass fires might cause the country to become thickened up to such an extent as to discourage the game and to decrease its visibility, the numbers of animals being perhaps reduced by shooting also in order to increase this effect. This method is mentioned here only that it may be stated that the resulting increase in humidity and improved shade conditions would be likely to prolong the hunger cycle so much as to prevent any possibility of causing starvation of the fly. Of course this method might render the environment unsuitable to tsetse in other ways.

5. *Organised Grass Burning.*

This, the converse of the last method, tends to attract the game into the country and to improve the visibility. These effects are almost certainly counterbalanced by the resulting increased severity in the physical conditions causing a shortened hunger cycle in the fly. The effects of the grass fire on 1st August 1929 in Sambala should be noticed in this connection (1930). Immediately following the fire flies in certain situations are exceptionally well-fed, apparently owing to the fact that fly and game are driven together into unburned patches. Such an effect, which is temporary and not important, was observed immediately after the grass fire in Shinyanga in 1931.

6. *Separation of Home and Feeding-grounds.*

In country where the woodland infested by *G. morsitans* at the edge of a fly-belt degenerates into scrub of *Acacia mellifera*, *A. drepanolobium*, *A. formicarum*, *A.*

seyal, *A. senegal*, *A. kirkii*, and associated Capparidaceae and other trees, together incapable of providing the tsetse with a permanent home, it is likely that large areas may be cleared of the hungry, wandering fly with which they are infested by cutting them off from the home by a clearing. The clearing need not be very wide, since the presence of an occasional tsetse on the wrong side will not prevent the keeping of stock. Such a measure, it seems, must cause the death of any flies which found themselves on the wrong side of the clearing when it was made. As such outer feeding-grounds in *Acacia* scrub on alluvial soil, together with the usual "hungry fringe" (page 477) of the fly-belt, may often extend out from the home to a depth of six miles or more, this method may be of great practical utility in gaining extra grazing for stock, or in enlarging a fly-free corridor between fly-belts.

7. Mr. Bax's "Winter Effect" Experiment.

Partly on the strength of the writer's supposition that a high evaporation-rate would be inimical to the fly (see also Nash, 1931, for the same supposition from another point of view), Mr. Bax conceived the idea of increasing the severity of the physical conditions by producing leafless bush throughout the year, and also of enhancing the desiccating effect of the dry season (winter).

Mr. Bax and the writer chose an area in Shinyanga known to have formed for over a year a well-populated haunt of *G. swynnertoni*. A larger portion being set aside as a control, an area of 100 acres was treated by Mr. Bax with a low-strength solution of arsenic pentoxide designed to kill the trees from the ground upwards, causing branches to drop off. The trees were mostly *Commiphora*, *Lannea*, and *Acacia* spp. Very small trees were slashed through, and most of the thicket was cut. The appearance of the area after a few days from the poisoning was quite dissimilar to the effect produced by sheer clearing which, would of course have been more expensive.

Exactly what effect these measures had on the fly has been the subject of discussion (see page 455). Before the area was treated (in early May) fly had been less numerous in the control than in the poisoned area, and the hunger of fly in the two sites had been about the same. Following the application of the poison, fly in the control in July showed a M.H.S. of 3.05, compared with 3.23 and 3.41 in different parts of the poisoned area, with a female percentage of 16.4 in the control plot as opposed to 29.0 and 31.9 in the poison. The apparent density of fly in the poison plot showed a fall.

Fly thus became hungrier and less numerous in the poison plot than in the control. As game became no more numerous in the poisoned area there was no reason to suppose that it had become any more suitable than the control as a feeding-ground, unless the slightly improved visibility had this effect. It was noticed that of flies marked in the poison plot 1 in 15.7 marked was recaptured there in the following 3 days, about the same as the proportion 1 in 12.3 for the recaptures during the first 3 days in the control plot of flies marked therein. But recaptures within 3 days of marking were 5.4 times as numerous as subsequent recaptures in the poison plot, whereas they were only 1.8 times as numerous in the control. That is, flies were recaptured normally in the poison plot for the first few days after marking, but afterwards did not tend to be retaken there. This disparity in the proportions of recaptures to flies originally marked in the poison and in the control plots respectively was not peculiar to flies marked in any particular stage of hunger. These facts, which are interesting, may or may not suggest that the poisoned plot was forming a feeding-ground.

The most interesting fact emerging from this experiment, however, is that the difference in fly condition between the two plots, noticeable enough in the dry season, was shown by Mr. Lloyd to have almost disappeared in the rains, when to the eye

the difference between the two sites was most marked owing to the flushing of the trees in the control. It would appear that the effect of the changes in atmospheric conditions is far greater than the effect of the vegetational screen in determining the hunger of the fly, or the type of woodland which the fly is able to inhabit. These considerations have obvious bearings on measures aiming at fly control by the alteration of the canopy of trees, or by general opening-up of the country.

8. *The Relation of Season to Fly Control.*

It will be appreciated from what has been said that, whether we attempt to destroy adult flies (*Glossina palpalis* excepted) attracted to baits living or inanimate, whether we attempt to produce starvation of the fly by a reduction in the numbers of its host animals, or whether we reduce the vegetational screen protecting it against the physical rigours of its environment, the maximal effect of such measures must be looked for in the height of the dry season, the late winter. During the remainder of the year the fly may be able largely to recover from whatever low density to which it may have been reduced by the combined effect of severe atmospheric conditions and the measures chosen for its control. Since organised grass burning, in countries where it is practicable, can be instituted in the dry season alone, these remarks apply with equal force to this method of control. Unless the fly can be exterminated in a single dry season by some sudden blow, the control campaign may drag on from year to year by reason of the uneven force exerted on the fly in different seasons. Thus, while it may be relatively easy to reduce tsetse-flies to a very low density, the need of the moment is some final measure to wipe out the few survivors. It is just conceivable that some such measure as the upsetting of the sex balance by the introduction of large numbers of male flies, from puparia collected elsewhere, might complete the destruction of a fly population reduced to a very low density by other means.

These remarks do not apply to the various methods of attack on the puparia such as have been investigated by Dr. Nash, where the effect of season is of less importance.

IX. Summary.

1. Tsetse-flies have been divided into four stages of hunger by their external appearance. These stages have been correlated with the internal appearance determined by dissection. It was found that the fat-bodies became maximally developed shortly after a meal, and thereafter diminished rapidly in bulk. Hunger of flies in samples is expressed as the Mean Hunger Stage (M.H.S.).

2. Flies in different stages of hunger showed different behaviour in the field. Thus hungry flies usually attacked head-upwards, replete flies, if attacking, tending to adopt a head-down attitude. Most replete flies preferred to settle on the ground, or on objects other than the members of the catching party. Hungry flies were the most persistent followers.

3. The true habitats and feeding-grounds of *Glossina morsitans*, *G. swynnertoni*, and *G. palpalis* are described, so far as they are known to the writer.

4. Confirmation of the feeding-ground theory was obtained for *G. swynnertoni* by an analysis of the to-and-fro movements of marked flies.

5. Considerable independent movement of flies was shown to occur in the absence of carriage on man or game. Some flies under such conditions travelled over 2 miles in 3 hours.

6. The effect of physical conditions on hunger of flies is discussed. The hunger cycle, or period required for a gorged fly to become hungry, was found to vary with the time of year, drier conditions shortening the cycle. Relative humidity and saturation deficit were the factors most closely associated with changes in hunger of flies in the field. The results were disturbed by certain "activity effects."

7. When flies were hungrier a greater proportion was found in feeding-grounds.
8. *G. palpalis*, unlike the other species, became apparently hungrier during the wetter season.
9. The abundance of game animals as determined by their seasonal migrations was found to be of almost no account beside the effect of the physical conditions in determining the hunger of the tsetse.
10. There was reason to suppose that *G. morsitans* can support itself on such small animals as pigs and dikdiks.
11. Evidence is brought to show that the classical type of concentration of *G. morsitans* described by earlier workers does not differ from the types of fly distribution described by Nash and the writer in 1930.
12. Control of tsetse by destruction of the adults proved difficult because during the damper seasons of the year hungry flies were few, and consequently few flies would attack the baits.
13. Complete game destruction would almost certainly eliminate fly. Casual methods of game destruction should be avoided until it is determined experimentally whether fly can subsist on small species difficult to exterminate.
14. Certain effects of preventing burning and of organised late annual grass burning are discussed.
15. A method of freeing areas of fly by separating the outer feeding-grounds and "hungry fringe" of fly-belts from the true habitat is suggested.
16. Defoliation of trees combined with removal of thicket proved more effective in the winter season than in the summer as a method of increasing hunger in tsetse, although to the eye the difference was much greater in summer.
17. It is concluded from the work as a whole that catching or trapping adult flies, attempting to starve flies by reduction in the numbers of hosts, or removing the screening vegetational canopy of their environment, will, except with *G. palpalis*, be really effective only in the height of the dry season, or winter.

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MOSQUITO SPECIES BREEDING IN "TEST" WATER CONTAINERS IN WEST AFRICA.*

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During the period from December 1925 to June 1926, Dunn (1927) carried out continuous observations on mosquito breeding in "test" water containers placed in strategic locations about the Compound of the West African Yellow Fever Commission near Lagos, Nigeria. These observations were made during most of the dry season and the initial part of the wet season.

In order to determine mosquito incidence in test containers during the months not covered in Dunn's study, supplemental observations at the same place were begun by the writer on 26th May 1928, and were carried through the wet season into the dry season to the end of the year.

Although the data here recorded are discontinuous with those of Dunn (a period of nearly two years intervening) and do not permit of analysis of one complete annual cycle of mosquito-breeding under the conditions imposed, they nevertheless provide contrasting data for the seasons involved. To be of real ecological significance and especially to interpret correctly such marked fluctuations as were found, for example, in the incidence of *Culex decens* in the two studies, data would have to be accumulated over several seasons.

Instead of the four types of containers employed by Dunn in each location, only his optimum type, bamboo sections, each containing water and two dead mango leaves, was used in the present investigation. Even though the water surface available at each station was thus approximately only one-quarter that exposed previously, the totals of breeding are still deemed comparable, since, other things being equal, the primary response of a mosquito seeking to oviposit in the vicinity of a particular station would probably be the presence of water, whether it be in one container or in four. On the other hand, no sample could have been considered crowded as compared with many "natural" infestations in water samples of approximately similar amounts encountered during other observations.

All but three of the ten containers were replaced in the identical locations established by Dunn in 1925. Those three (nos. 5, 6, and 7) were moved in the present study in order to maintain comparable environmental conditions with relation to vegetation and distance from human habitation, because of the expansion of the compound during the intervening months. In this study, as in the previous study of Dunn, the same assistant performed routine examinations and collected infested samples.

The environment at each location may be briefly described as follows: Containers nos. 1, 2, and 10 were under buildings, which, as is necessary in the tropics, were superimposed on pillars about 3 feet off the ground. These containers were protected from rain. Containers nos. 3 and 4 were in tropical "bush" sufficiently dense to exclude sunlight and to afford considerable protection from rain. The other five containers (nos. 5 to 9, inclusive) were more or less exposed to wind, rain, and, at least, intermittent sunshine. The distance of each station from the nearest human habitation is indicated in Table I.

* The studies and observations on which this paper is based were conducted with the support and under the auspices of the International Health Division of the Rockefeller Foundation.

Treatment and Examination of Containers.

Fresh bamboo joints, approximately 3 inches in diameter, were secured, numbered, filled with rain-water with two dead mango leaves protruding, and placed in location to age for two weeks before observations were begun. Then, on 26th May, they were thoroughly brushed, refilled as before, and replaced. The first observations were made on 1st June and at five-day intervals thereafter. By pouring the contents of each container into a white enamel basin, an infestation was quickly detected. If no infestation was observed, the sample was replaced in the container. Infested samples were removed to the laboratory, where the containers were rinsed and the samples, together with the mango leaves, were placed in large petri-dishes for subsequent rearing and identification of the mosquitos. Rain-water was used as long as it was available; later, with the advent of the dry season, tap-water had to be resorted to, but, since filtration rather than chemical methods are used for treatment at the source of the Lagos water-supply, this was not deemed an important variable.

Agitation of the surface of the water in containers, such as occurs during rain storms, caused most larvae to go below, and to return for brief intervals only long enough to breathe. The respiration process is materially aided during submergence, especially in the younger stadia, by the anal gills. Several checkings of counted larvae exposed during a severe storm showed practically no reduction in numbers. It is not considered, therefore, that the loss was significant in the five partly exposed containers during overflowing resulting from heavy rains.

Species of Mosquitos infesting "Test" Water Containers.

It is obvious that only a part of the indigenous mosquito species possess habits that would permit breeding in these water samples. However, a surprising proportion of the Culicine species in Southern Nigeria will breed in small collections of water such as gather in tree-holes, stumps in harvested bamboo thickets, rock depressions, crab-holes, utensils, bilge-water in boats, and the like, and it is this part of the mosquito population that is of immediate interest in relation to the yellow fever problem.

TABLE I.
Incidence of all Species at each Station with Comparison of Data for 1926 (Dunn).

Station numbers	1	2	3	4	5	6	7	8	9	10	Total
Location and distance from nearest habitation	Under laboratory	Under dormitory	Among dense trees, 9 yds.	In thick "bush," 70 yds.	In long grass, 45 yds.	Ex-posed, 25 yds.	In short grass, 100 yds.	Shaded; near animal house, 33 yds.	Sunny; by animal house, 16 yds.	Under animal house	Total
Positive infestations during 440 observations ...	12	21	18	16	10	14	9	18	21	16	155
Emergence, all species ...	349	657	527	309	327	559	260	835	824	372	5,019
Infestations during 390 observations by Dunn, 1926	10	14	34	27	12	23	35	34	29	21	239
Difference in number infestations, 1926 and 1928	-2	-7	16	11	2	9	26	16	8	5	84

As compared with total emergence of 6,590 obtained by Dunn; details of emergence, all species in his containers, not stated.

The total number of five-day observations of the ten containers was 440, the number of infestations found was 155. The ratio was therefore 35.25 per cent., as compared with the ratio of 61.28 per cent. previously observed by Dunn, based on 239 positive of 390 observations, and considering the four containers at each of the stations as a unit, or 15.32 per cent., based on 1,560 individual observations of the forty containers. Details of the number of infestations and total emergence from the containers are presented in Table I.

Effective variables which could account for this difference in frequency or percentage infestation are:—(1) time, either seasonal or yearly, which will be discussed later in connection with Table III; (2) number of containers at each station, four as against one (a doubtful factor, mentioned previously); and (3) multiple oviposition by the same mosquito in more than one of Dunn's containers at any one station, which would increase his number of positive samples at a particular observation.

Daily records were made of the total emergence and the sex of mosquitos reared from the various samples as well as of the numbers of specimens failing to emerge. Since the yellow fever problem in West Africa was the paramount issue with the Commission, the incidence and sex ratio of only the natural and potential mosquito vectors of yellow fever infesting the total samples are given in Table II.

TABLE II.

Numbers and Sex of Mosquitos reared from "Test" Water Container Infestations with special reference to Species capable of Yellow Fever Transmission.

Species	Sex	Station numbers										Totals
		1	2	3	4	5	6	7	8	9	10	
<i>Aedes aegypti</i>	♂	157	185	168	24	151	182	90	353	221	121	3135
	♀	126	179	103	13	161	177	71	388	173	92	
<i>Aedes luteocephalus</i>	♂		9	88	18		20	4	2	22	7	326
	♀		15	67	17		12	—	5	27	13	
<i>Aedes africanus</i>	♂		10	3	33	1	30	22	—	2	1	206
	♀		17	7	35	4	29	11	1	—	—	
<i>Aedes stokesi</i>	♂			2			1	2		—	1	9
	♀			1			1	—		1	—	
<i>Aedes simpsoni</i>	♂						—			16		32
	♀						2			14		
<i>Eretmopodites chrysogaster</i>	♂				47	2	4		37	4	8	206
	♀				42	5	8		45	1	3	

It is interesting to note that two-thirds of the total numbers of *A. aegypti* and one-half of the *E. chrysogaster* were reared from the three containers located in the vicinity of the animal houses. The remainder of the *chrysogaster* were found in the "bush" locations. The latter species probably seldom attacks man. On the other hand, only four of 208 *A. africanus* were reared from these three containers. This species was completely absent only from container no. 1 during the period of observation, but it preferred the more distant locations, while *luteocephalus* never infested containers nos. 1 and 5. Both *africanus* and *luteocephalus* adults would probably feed readily on man, given such opportunity out-of-doors. However, collections of adult mosquitos from inside habitations in and about Lagos, covering a period of more than a year, indicated that if these two species enter houses, they must do so at night, and such a habit would not be traceable by means of daytime sampling.

Infestations involving single or few individuals of certain of the species listed in Table II occurred, surprisingly enough, several times during the five-day periods of observation, indicating restricted ovipositing at certain times.

In Table III, the total numbers of collections and of reared species at the ten stations observed by Dunn are compared with those observed in this study.

TABLE III.

Species occurring and Number of Adults reared at all Stations in 1928, and Comparison with Data for 1926 (Dunn).

Species	Number of collections		Number of adults		Numerical rank	
	1926	1928	1926	1928	1926	1928
<i>Aedes</i>						
(<i>Stegomyia</i>) <i>aegypti</i> (Linn.)...	204	133	4,508	3,135	1	1
" <i>luteocephalus</i> (Newst.)...	30	32	344	326	4	3
" <i>apicoargenteus</i> (Theo.)...	9	6	92	62	7	7
" <i>simpsoni</i> (Theo.) ...	11	4	92	32	8	8
" <i>africanus</i> (Theo.) ...	3	24	25	206	10	6
(<i>Aedimorphus</i>) <i>stokesi</i> , Evans ...	1	5	1	9		10
(<i>Finlaya</i>) <i>longipalpis</i> (Grünb.) ...		2		3		
<i>Culex</i>						
(<i>Culicomyia</i>) <i>nebulosus</i> (Theo.) ...	16	28	741	808	2	2
(<i>Cyathomyia</i>) <i>horridus</i> , Edw. ...	6	12	93	219	6	4
(<i>Eumelanomyia</i>) <i>albiventris</i> , Edw. ...		1		10		9
<i>decens</i> , Theo. ...	6	1	544	3	3	
<i>duttoni</i> (Theo.) ...	1		34		9	
<i>Lutzia tigrripes</i> (Grp.) ...	1		6			
<i>Eretmopodites chrysogaster</i> (Grah.) ...	22	17	108	206	5	5
<i>Megarhinus brevipalpis</i> (Theo.) ...	2		2			
Totals ...	312	265	6,590	5,019		

The shift in numerical rank of *C. decens* and of *A. africanus* in the two studies is noteworthy. Whether these differences represent seasonal responses or populational trends in the "natural cycles" of the species cannot be stated on the basis of these meagre data, but the latter seems more probable.

Infestations of two or more species were frequently encountered in a single container. The maximum number of species occurring simultaneously was five on four occasions, all at the beginning of the dry season. This condition was found only once in Dunn's observations, when *Aedes aegypti*, *A. africanus*, *A. luteocephalus*, *Culex nebulosus*, and *C. horridus* were reared by him from the same sample. This same group was found on two occasions in our study, once in container no. 1 and once in container no. 2. The same association was found also in nos. 9 and 10, except that *Eretmopodites chrysogaster* replaced *A. africanus* in the former, and *C. decens* replaced *C. horridus* in the latter.

Occurrence of *Aedes aegypti*.

As in Dunn's study, *A. aegypti* occurred more frequently in our sample than did all the other species combined, while container no. 8, situated at 33 yards from the animal stock house, in the shade, proved to be most abundantly infested by this

species in both studies. Contrary to Dunn's findings, however, container no. 7, located at 100 yards in the "bush" at the east end of the Compound, was second least visited by *A. aegypti*; furthermore, no. 1, which was under the laboratory, was well infested, while in the former study the container in a similar position showed decidedly the least number of positive samples for this species. Whether the reversal in popularity of these two containers was associated with protection or exposure during the two seasonally contrasting periods is not clear. Dunn's statement that "... the females (of *A. aegypti*) may prefer the places of concealment afforded by grass and bush at a short distance from habitation to those in the more immediate vicinity or inside the houses ..." is only partly supported in this study, since the containers immediately under buildings (nos. 1, 2 and 10) had about average infestations with *A. aegypti*. It may be added, however, that adult mosquito collections from inside the habitations previously mentioned showed that *A. aegypti* was considerably in the minority among domestic species captured indoors, despite the well known fact of its frequent nocturnal visitation there. On the other hand, such adult collections yielded in abundance *Culex nebulosus*, a domestic breeder whose females probably favour avian blood exclusively. This characteristic of *Culex nebulosus* was determined by Davis & Philip (1931) in precipitin tests of fresh blood-meals of naturally-fed mosquitos. *C. nebulosus* was the second most abundant species taken from the containers in the immature stages in both the 1926 and 1928 studies.

A comparison of the number of infestations of *A. aegypti* in the various containers in the two studies will be found in Table IV.

TABLE IV.
Total Breeding of Aedes aegypti at each Station, 1926 and 1928.

Station		1	2	3	4	5	6	7	8	9	10	Totals
Number of infestations	1926 ...	6	10	31	16	12	21	27	32	30	19	204
	1928 ...	12	17	15	12	10	10	7	14	17	14	128
Total adults reared 1928		283	364	271	37	312	359	161	741	394	213	3,135
Sex ratio of adults 1928	Males ...	157	185	168	24	151	182	90	353	221	121	1,652
	Females	126	179	103	13	161	177	71	388	173	92	1,483

Total breeding in all 4 of Dunn's containers at each station; data for numbers of adults reared by him not available for comparison.

The total number of adults reared and the sex ratio obtained in 1928 are also shown in this table, although comparable figures are not available for the previous study. As in Table I, considering all the species found, the first two containers are the only ones that show more infestations in 1928 than in 1926, whereas container no. 7 revealed approximately one-fourth, nos. 3, 6 and 8 one-half, and no. 9 nearly one-half the number previously obtained. That the total number of infestations in any one container is not necessarily a criterion of the adult replacement potential is well illustrated by the data for no. 8, which was infested fourteen times, producing 741 adults (388 females), while no. 10, with a similar number of infestations, yielded only 213 *A. aegypti* (92 females). Again, while only seven samples were positive in no. 7, which gave 161 adults, twelve infestations in nos. 1 and 4 produced 283 and 37 adults respectively.

A like dissimilarity between the number of infestations by month and the total number of adults reared is seen in comparing Tables V and VI. In June, for example,

nineteen positive samples yielded 714 adult *A. aegypti*, whereas twenty-four such samples in July produced only 345 adults. Little need be said concerning the correlation of rainfall and the observed incidence of *A. aegypti*, unless it be remarked that, whereas, in Dunn's observations, breeding increased "with the beginning of the rainy season," his figures for the number of infestations during the period 5th December to 31st December being relatively low, abundance was greatest in the present study in

TABLE V.

Number of Infestations of Aedes aegypti at each Station in relation to Monthly Rainfall.

Month	Station numbers										Monthly total	Rainfall
	1	2	3	4	5	6	7	8	9	10		
June	1	1	1	3	1	2	1	3	4	2	19	15.68
July	2	4	3	2	—	1	2	5	2	3	24	2.66
August	2	2	2	3	1	1	1	—	1	1	14	2.46
September	—	2	1	—	1	2	—	2	2	2	12	5.73
October	1	1	1	1	1	—	—	—	2	2	9	11.48
November	1	2	2	—	3	—	1	3	4	2	18	1.62
December	5	5	5	2	3	4	2	1	2	2	31	0.03
Station total	12	17	15	11	10	10	7	14	17	14	127	X

TABLE VI.

Number of Adult Aedes aegypti reared from Samples during each Month.

Month	Station numbers										Monthly total
	1	2	3	4	5	6	7	8	9	10	
June ...	8	16	20	15	32	138	30	336	104	15	714
July ...	31	48	23	9	—	36	7	144	5	42	345
August ...	11	16	48	7	17	6	24	—	5	1	135
September	—	25	8	—	77	42	—	13	16	31	212
October ...	16	45	4	2	7	—	—	—	38	21	133
November	30	90	19	—	140	—	12	242	128	39	700
December	187	124	149	4	139	137	57	6	47	64	914
Station totals ...	283	364	271	37	412	359	130	741	343	213	3,153

December, and there appeared to be a decrease during the heaviest part of the rainy season. It may well be that there is a point of optimum rainfall up to which a general population increase occurs, as was the case in 1926, but above which conditions become unfavourable and cause breeding activities again to decrease. The problems of biotic potential of *A. aegypti* here involved are intimately concerned with such little-known factors as natural longevity of females, number of blood-meals, and total

TABLE VII.

Number of Species and Individuals reared (September to December) from Containers in Centre of Lagos (no. 11), a suburban Village on the Mainland (no. 12), and in dense Bush (no. 13), about 9 miles inland.

Species	Month	Container numbers					
		11		12		13	
		Males	Females	Males	Females	Males	Females
<i>Aedes aegypti</i>	Sept.	—	—	21	15	—	—
	Oct.	24	24	37	47	—	—
	Nov.*	29	33	—	—	—	—
	Dec.	19	—	7	6	1	1
<i>Aedes africanus</i>	Sept.	—	—	2	3	—	—
	Nov.*	—	—	—	—	1	—
	Dec.	2	1	1	1	8	6
<i>Aedes luteocephalus</i>	Sept.	—	—	26	35	—	—
	Oct.	—	—	23	26	—	—
	Nov.*	—	—	11	18	—	—
	Dec.	—	2	18	12	—	—
<i>Aedes apicoargenteus</i>	Sept.	—	—	—	—	11	8
	Dec.	—	—	—	1	14	19
<i>Aedes stokesi</i>	Sept.	—	—	—	—	3	5
	Oct.	—	—	2	—	14	10
	Nov.*	—	—	—	—	13	13
	Dec.	—	—	—	—	9	10
<i>Aedes longipalpis</i>	Sept.	—	—	—	—	22	32
	Oct.	—	—	9	5	16	19
	Nov.*	1	1	—	—	61	89
	Dec.	—	—	—	—	155	165
<i>Culex nebulosus</i>	Sept.	—	—	5	2	2	1
	Oct.	—	—	19	15	—	—
	Nov.*	—	8	—	—	—	—
	Dec.	—	—	—	—	2	1
<i>Culex horridus</i>	Sept.	—	—	1	5	—	—
<i>Megarhinus brevipalpis</i>	Oct.	—	—	—	—	—	1

* Data for examinations of container no. 12, 20–25–30th Nov., are missing.

number of eggs laid. In other words, it is conceivable that, with the advent of favourable conditions such as perhaps a decrease of heavy rains, successive egg-laying by older females added to the first ovipositions of young females would build up an *Aedes* population quite rapidly.

At present our information on the longevity of *A. aegypti* is based chiefly upon the unnatural conditions obtaining in confinement. Many females accept six to eight blood-meals in captivity, and the writer has kept certain such *A. aegypti* alive for 150 to 201 days in seven instances. Two of these lots were withheld from blood for periods of two to four and eight to seventeen days before being given their initial blood-meal on 29th September and on 21st December respectively; the last insects in the lots died on 23rd March and 14th May, having lived through the entire dry season in an open screened cage of the type described by Stokes, Bauer & Hudson (1928), with only a petri dish moisture-pad and sugar-solution pad available within. The rigours of the harmattan or dry season are characterized by extremes of relative humidity. A Freiz hydrothermograph, type 207, recorded for 2nd January, a drop from 74 per cent. at 8 a.m. to 14 per cent. at 4 p.m., and diurnal fluctuations of 35 per cent. were not infrequent during the month. Survival in confinement under these conditions (recorded on an instrument on the same shelf) makes one wonder just how deleterious the dry season is in nature, excluding the factor of reduction of breeding-places to aestivating adults *per se*, when they are allowed to choose their own resting quarters. On the other hand, cages of segregated females, given no opportunity of taking blood-meals but having water and fresh sugar-solution continuously available, have been maintained in the laboratory for as long as 74 days, to the death of the last insect. (Mosquitos were liberated in the cage from 27th April to 1st May; the last insect was found dead on 13th August.)

Occurrence of Breeding in other Containers.

Three additional bamboo containers were maintained, operated, and examined in a manner comparable to those on the Compound—one in the heart of the city of Lagos, one in the Botanical Gardens in a suburb, Ebute Metta, and one in the dense "bush" about 2 miles inland from the Compound. These were numbered 11, 12 and 13 respectively. No. 11 was placed in a school yard near Tinubu Square surrounded by native residences, shops, and the like. The environment surrounding no. 12 has been described previously (Philip, 1931). Container no. 13 was a natural bamboo stump (harvested) on the edge of a bamboo thicket about half a mile from the town of Makoli on the road to Ibadan. The last two were continuously shaded, the first more or less so, under a flamboyant tree. Observations were begun on 1st September and terminated 31st December. The species of mosquitos encountered and their monthly incidence are summarised in Table VII. The almost complete absence of *A. aegypti* from container no. 13, which was isolated in the "bush," is perhaps to be expected. The low incidence of *A. africanus* in nos. 12 and 13 is surprising in view of its occurrence in containers about the Compound. In this and other studies, *A. luteocephalus* was always most prevalent in marginal or semi-inhabited territory, that is, it was practically absent from areas of dense population, as well as from thick bush with scattered population. *A. stokesi*, *A. apicoargenteus*, and especially *A. longipalpis* seem to prefer dense cover for breeding-places. The occurrence of the extremely domestic *C. nebulosus* in small numbers in container no. 13 is interesting.

Summary.

Observations additional to those made by Dunn (1927) of Culicine mosquitos breeding in "test" water containers about a Compound in Southern Nigeria, near Lagos, are here reported for a period of the year (June to December) not covered in Dunn's study. Only the optimum type of container mentioned in Dunn's report (bamboo joints containing water and mango leaves) was employed, and these were

placed in the same ten representative environmental situations. The numerical rank of infesting species differed significantly in the two studies only in the case of *Culex decens*, which dropped from third to last place, and of *Aedes africanus*, which rose from tenth to sixth place. The total numbers of infestations in the former study were greater, but this is explainable on the basis of one or several variables, *i.e.*, seasonal differences, elapse of time between studies, or less probably the fact that there were four containers instead of one at each station. The number of infestations at any one station has little relation to the number of resultant adults; there is a wide variation in these numbers.

An analysis of the occurrence of *A. aegypti* in containers and a discussion of certain bionomical information together with relative weather conditions are included. Brief data are also presented of the incidence of species at three additional stations, one in a centre of dense population (Lagos), one in a suburb (Ebute Metta), and the third isolated in dense "bush."

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STUDIES ON THE ABUNDANCE, DISTRIBUTION AND FEEDING HABITS OF SOME WEST AFRICAN MOSQUITOS.*

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Introduction.

The studies reported in this paper were undertaken at the suggestion of Dr. Henry Beunwkes, Director of the West African Yellow Fever Commission, for the purpose of securing additional information regarding the life habits in Nigeria of species of mosquitos which had been found experimentally to be vectors of yellow fever; for in order to determine the rôle of these experimental vectors in the epidemiology of yellow fever, it is necessary to have information regarding their geographical distribution or range, their breeding-places, their abundance inside and outside of human habitations, the seasonal variations in their abundance, the time and place of their feeding, and their preferred blood-meal.

The studies were made for the most part in and around Lagos, especially in the vicinity of Yaba, where the laboratory of the West African Yellow Fever Commission is situated. A few observations were made in the city of Ibadan, which is about 100 miles inland from Lagos in the forest belt, and a still more limited number were made in Kano, which lies in a semi-arid region about 500 miles inland from Lagos.

Methods of Study.

The following four methods were used to secure information regarding the life habits of the mosquitos :—

1. *Daytime captures of adult mosquitos inside of houses.*—Daytime captures were made in houses in the suburbs of Lagos by specially trained native boys working under the direct supervision and observation of the author or of his assistant. About 15,000 adult mosquitos were taken. Because of the construction of the houses searched, which were mostly those of natives, the "room" was found to be the best unit upon which to base comparisons of mosquito density. Use has also been made in this study of the results of a series of daytime house captures by the late Dr. T. B. Hayne (Table I).

2. *Rearing adults from larvae.*—This method was little used in the study for two reasons: first, because extensive observations, particularly of the tree-hole-breeding species of *Aedes*, had previously been made by this method in the same area in which our work was done; and second, because we were primarily interested in those species which bite men.

3. *"Standard" night catches with human bait.*—It was necessary to devise some method by which to measure the density of those species which are abundant but which are not found in appreciable numbers inside of houses. To serve this purpose the "standard" night catch was developed. This consisted of the mosquitos caught by a native boy while they were attempting to bite him. Inasmuch as the non-domestic-breeding mosquitos of Nigeria were soon found to be either crepuscular or nocturnal in their time of activity, the standard night catches were begun at sunset and were continued for a period of three hours. The mosquitos taken during the

* The studies and observations on which this paper is based were conducted with the support and under the auspices of the International Health Division of the Rockefeller Foundation.

first hour and a half were kept separate from those taken during the second hour and a half (Tables II, III, IV). Very satisfactory results were secured with this method, and the native boys were found to be relatively easy to train. Horses and cattle are not available for use as animal bait in the vicinity of Lagos because of the trypanosomiasis problem. And, furthermore, we were primarily interested in observing which mosquitos bite man.

TABLE I.

*Results of Daytime Catches of Adult Mosquitos made inside Native Houses in small Bush Villages near Yaba, from 30th April to 24th July, 1930.**

Species	Number of mosquitos taken		
	In villages on shore of Lagos lagoon	In villages inland from Lagos lagoon	Total
<i>Anopheles costalis</i>	8,284	3,814	12,098
<i>Culex nebulosus</i>	737	738	1,475
<i>Mansonia (Mansonioides) spp.</i>	479	398	877
<i>Culex spp.</i>	28	11	39
<i>Aedes aegypti</i>	19	5	24
<i>Anopheles pharoensis</i>	18	3	21
<i>Aedes nigricephalus</i>	9	1	10
<i>Aedes irritans</i>	5	0	5
<i>Aedes luteocephalus</i>	0	2	2
<i>Uranotaenia annulata</i>	2	0	2
<i>Aedes domesticus</i>	0	1	1
Total	9,581	4,973	14,554
Number of villages	4	14	18
Number of catches made	180	69†	249

* These catches were made under the direction of the late Dr. T. B. Hayne.

† Of these catches 33 were made in one village.

The boys were found to differ somewhat in attractiveness to mosquitos and in skill in catching the insects, but this difficulty was overcome in part by making repeated catches at the same stations with different boys in rotation and averaging the results, and in part, especially in short series of observations, by using the same boys at the same places. The boys soon became accustomed to the mosquito bites and, so far as could be determined, suffered no inconvenience from them. Quinine was administered whenever requested, and no more than the usual amount of malaria occurred among the boys.

Observations were made by this method during the period from September 1930 to September 1931. About 400 standard night catches were made in the vicinity of Lagos, about fifty in Ibadan, and eighteen in Kano; and approximately 26,000 mosquitos were taken and identified. Our conclusions regarding variations in mosquito density in different seasons and at different places are based on the results of certain special series of these catches.

4. *All-night catches.*—These catches were made by two boys stationed at the same place from sunset to sunrise. In order to have as few variable factors as possible, the same two boys worked all through the night. They were visited occasionally by the author or his assistant. The mosquitos which were caught during each hour of the night were kept separate, so that the time of activity of the various species taken could be determined; 7,640 adult mosquitos were captured and identified.

In Table V are summarised the results of ten of these all-night catches. The results of seven additional all-night catches are not included in this summary because the catches were made at slightly different hours, but the result of these additional catches were similar to those tabulated.

TABLE II.

Results of twenty standard Night Catches made at Ikoyi (Lagos) during the Dry Season, 16th January 1930 to 13th May 1931.

Species	Number of females taken		
	First 90 min.	Second 90 min.	Total 3 hours
<i>Anopheles costalis</i>	13	98	111
„ <i>marshalli</i>	0	1	1
<i>Mansonia africana</i>	0	1	1
<i>Aedes aegypti</i>	5	1	6
„ <i>africanus</i>	5	1	6
„ <i>luteocephalus</i>	14	3	17
„ <i>vittatus</i>	1	0	1
„ <i>stokesi</i>	2	0	2
„ <i>irritans</i>	31	12	43
„ <i>nigricephalus</i>	6	0	6
<i>Culex consimilis</i>	0	4	4
„ <i>thalassius</i>	4	7	11
„ <i>tritaeniorhynchus</i>	6	5	11
„ <i>duttoni</i>	1	0	1
„ spp. (<i>pipiens</i> group)	2	1	3
„ spp.	3	8	11
Unidentified (mostly <i>Uranotaenia</i> and similar species)	15	1	16
Total	108	143	251

List of Species of Mosquitos studied.

The fourteen West African species of mosquitos which experiments have shown to be of potential importance in the transmission of yellow fever may readily be divided into three groups, as follows :—

Group I.—The vector of yellow fever

Aedes (*Stegomyia*) *aegypti*, Linn.

Aedes (*Stegomyia*) *luteocephalus*, Newst.

Aedes (*Stegomyia*) *africanus*, Theo.

Aedes (*Stegomyia*) *simpsoni*, Theo.

Aedes (*Stegomyia*) *vittatus*, Bigot xvi

Aedes (*Aëdimorphus*) *stokesi*, Evans
(=*apicoannulatus*, Edw.)

Eretmopodites chrysogaster, Graham

Mansonia (*Mansonioides*) *africana*, Theo. 5

Culex (*Culex*) *thalassius*, Theo. — (xviii, (196) x)

Group II.—Experimental vectors (those species which have been shown by transmission experiments to be capable of transferring the virus of yellow fever by their bites)

Aedes (*Aëdimorphus*) *irritans*, Theo. xv

Aedes (*Aëdimorphus*) *nigricephalus*, Theo.

Aedes (*Banksinella*) *punctocostalis*, Theo.

Aedes (*Banksinella*) *lineatopennis*, Ludl.

Mansonia (*Mansonioides*) *uniformis*, xx 2
Theo.

Group III.—Species non-lethal to the virus (those species which have been shown to be capable of retaining the virus of yellow fever throughout their lives, but which have not been shown to be capable of transferring it by their bites)

We also secured information regarding a number of other species, which are listed below. There is definite evidence to show that the three most abundant of these species, namely, *Anopheles costalis*, *Culex* spp. (*pipiens* group), and *C. nebulosus*, are not concerned in the transmission of yellow fever, but because of their abundance we have discussed them separately. Most of the remaining species listed are rare and therefore cannot be of much importance in the epidemiology of yellow fever. There is good reason to believe that even those which are moderately abundant at times are unimportant from this standpoint. Most of the data which we secured regarding the following species are set forth only in the accompanying tables.

Anopheles (*Anopheles*) *mauritanus*, Grp.
Anopheles (*Anopheles*) *obscurus*, Grünb.
Anopheles (*Myzomyia*) *pharoensis*, Theo.
Anopheles (*Myzomyia*) *gambiae*, Giles (= *costalis*, Lw.)
Anopheles (*Myzomyia*) *funestus*, Giles
Anopheles (*Myzomyia*) *hargreavesi*, Evans
Anopheles (*Myzomyia*) *moucheti* var. *nigeriensis*, Evans
Anopheles (*Myzomyia*) *marshalli*, auctt.
Uranotaenia (*Pseudoficalbia*) *annulata*, Theo.
Uranotaenia (*Pseudoficalbia*) *mashonaensis*, Theo.
Mucidus mucidus, Karsch.
Aedes (*Stegomyia*) *apicoargenteus*, Edw.
Aedes (*Aedimorphus*) *domesticus*, Theo.
Aedes (*Aedimorphus*) *punctothoracis*, Theo.
Aedes (*Aedimorphus*) *albocephalus*, Theo.
Aedes (*Aedimorphus*) *cumminsi*, Theo.
Aedes (*Aedimorphus*) *hirsutus*, Theo.
Aedes (*Dunnius*) *argenteoventralis*, Theo.
Mansonia (*Coquillettidia*) *annetti*, Theo.
Mimomyia splendens, Theo.
Ficalbia spp.
Culex (*Culex*) *quasigelidus*, Theo.
Culex (*Culex*) *annulioris* var. *consimilis*, Newst.
Culex (*Culex*) *tritaeniorhynchus*, Giles
Culex (*Culex*) *duttoni*, Theo.
Culex (*Culex*) spp. (*pipiens* group)
Culex (*Neoculex*) *rima*, Theo.
Culex (*Culiciomyia*) *nebulosus*, Theo.

The ecological data which we have secured on each species are classified in the order indicated in the introduction. To facilitate the presentation of the evidence, the species are grouped according to genera.

***Aedes* (*Stegomyia*) *aegypti*.**

Extensive studies have recently been made in Nigeria¹ regarding the breeding places and the prevalence of this species, which has long been known to be abundant and very active inside of houses. Dunn² found it breeding in tree-holes in considerable numbers. However, we obtained this species relatively rarely in our night catches out-of-doors. The data in Table II are typical of our findings, which indicate that *A. aegypti* is crepuscular in its time of activity.

***Aedes (Stegomyia) africanus* and *A. (S.) luteocephalus*.**

These two species are very similar in their habits and will be considered together.

Breeding-places.—Both species breed principally in tree-holes (Table VI), although in the past they have occasionally been found breeding in domestic water-containers.³

Abundance inside of houses.—Records in the literature show that these two species have been taken inside of houses in West Africa, but always in small numbers^{3,4}. On the other hand, in an extensive series of house captures of adult mosquitos made in 1930–31 in the four largest cities of Nigeria, not a single adult of either of these species was taken.¹

In a series of house captures which we made in the suburbs of Lagos, neither species was included among 15,439 adult mosquitos taken, and in another series of house captures, made in the village of Mushin in houses close to Stations M4 and M7, where very large numbers of both species were taken out-of-doors, not a single mosquito of either species was obtained. In addition, in 249 daytime house captures made by the late Dr. T. B. Hayne* in small native villages in the vicinity of Lagos, all closely surrounded by bush in which there was known to be a heavy production of both species, no *A. africanus* and only two *A. luteocephalus* were found among a total of 14,554 adults taken (Table I).

TABLE III.

Results of fifteen standard Night Catches made at Iwomran from March to April 1931.

Species	Number of females taken		
	First 90 min.	Second 90 min.	Total 3 hours
<i>Aedes nigricephalus</i>	270	159	429
.. <i>irritans</i>	133	42	175
.. <i>luteocephalus</i>	89	26	115
.. <i>africanus</i>	8	0	8
<i>Mansonia uniformis</i>	27	67	94
.. <i>africana</i>	6	17	23
.. spp. (rubbed)	10	4	14
<i>Anopheles costalis</i>	18	26	44
<i>Culex thalassius</i>	5	15	20
Others*	8	3	11
Total	574	359	933

* Includes: *Aedes aegypti* 1, *Ae. punctothorax* 5, *Culex tritaeniorhynchus* 1, *Culex duttoni* 1, *Mimomyia splendens* 1, and unidentified 2.

Abundance outside of houses.—In striking contrast to the rarity of these two species inside of houses was their profusion out-of-doors. Their relative abundance during the year over which our observations extended is shown in the totals given in Table V. However, we found many places in which, especially during the rainy season, these were the most numerous of the mosquitos active during the early evening. Among these places was Mushin (Table VII), where we attempted to study the correlation between rainfall and the abundance of these two species. The great increase in the numbers caught after a period of rainy weather, and the great decrease, almost to the point of disappearance, during the dry season, indicates very definitely their complete dependence upon rain to fill the tree-holes which are their breeding-places. That

* The untimely death of Dr. Hayne from yellow fever, on 11th July 1930, at Lagos, prevented him from concluding studies of the type here reported.

these two species are very prevalent during the rainy season in the bush near Lagos is well indicated by the data in Tables II, III, IV. Furthermore, a single *A. luteocephalus* was taken in Kano during the rainy season of 1931 in the act of biting (Table VIII).

Time of feeding.—Table V presents fairly conclusive data that the principal time of activity of *A. africanus* and *A. luteocephalus* is crepuscular. This evidence is confirmed by the results of the standard night catches, which show that the number of these mosquitos taken during the first hour and a half is consistently much higher than the number taken in the second hour and a half. The results of a large number of standard night catches are summarised in Tables II and III.

TABLE IV.

Results of forty-five standard Night Catches made during the Rainy Season of 1931 in Cocoa Groves in which Eretmopodites chrysogaster was breeding.

Species	Number of female mosquitos taken		
	Ikeja vicinity	Ibadan	Total
<i>Eretmopodites chrysogaster</i>	0	1	1
<i>Mansonia africana</i>	910	38	948
<i>Aedes luteocephalus</i>	234	15	249
<i>Aedes africanus</i>	193	29	222
<i>Culex</i> spp. (<i>pipiens</i> group)	53	2	55
<i>Anopheles hargreavesi</i> *	53	3	56
<i>Aedes irritans</i>	36	0	36
<i>Mansonia uniformis</i>	23	0	23
<i>Culex consimilis</i>	20	1	21
<i>Anopheles mauritanus</i>	5	0	5
<i>Anopheles costalis</i>	3	3	6
<i>Aedes cumminsii</i>	0	6	6
Others†	14	7	21
Total	1,544	105	1,649
Number of species taken	18	13	23
Number of catches	27	18	45

* Includes a few *An. moucheti* var. *nigeriensis*.

† Includes: *Anopheles obscurus* 1, *Mansonia annetti* 2, *Aedes lineatopennis* 3, *Aë. aegypti* 1, *Aë. domesticus* 1, *Aë. vittatus* 3, *Aë. apicoargenteus* 1, *Culex thalassius* 4, *C. tritaeniorhynchus* 1, *C. nebulosus* 1, *Mucidus mucidus* 3.

An attempt was made to prove that the small numbers of those two species taken as the night progressed was due not to their depletion through the capture of the females which attempted to bite, but mainly to a relative unwillingness of the mosquitos to bite after the time of their principal activity had passed. The results of the observations made for this purpose are set forth in Table IX, but unfortunately these mosquitos were not very numerous during the period of observation. A series of six night catches was made on successive nights by the same two boys at the same two places. Standard night catches were made on alternate nights, but the mosquitos caught during each half hour of the three-hour period were kept separate. On the other nights similar three-hour catches were made, but they were begun two hours after sunset instead of at sunset. The number of *A. africanus* and *A. luteocephalus* taken in the earlier catches was consistently higher than in the later catches. Furthermore, the curve of the number caught hour by hour is very similar to that indicated in Table V.

Place of feeding.—Evidence that these two species bite man very frequently outdoors has been presented. In Nigerian villages natives of all ages are abroad in the cool of the early evening, just at the time when these mosquitos are most active.

The rarity with which these species are found indoors and the fact that human beings are so readily available out-of-doors makes it seem improbable that the mosquitos enter houses to feed.

Preferred blood-meal.—We have shown that *A. africanus* and *A. luteocephalus* bite man with great frequency, but we have not been able to demonstrate that human blood is the preferred blood-meal of these two species. Unfortunately, the precipitin test cannot be used to secure this information, because it is almost impossible to find engorged females in nature.

TABLE V.

Results of ten all-night Catches made in the Vicinity of Lagos, 1931.

Species	No. of times taken	Number of female mosquitos taken												Total
		7-8 p.m.	8-9 p.m.	9-10 p.m.	10-11 p.m.	11-12 p.m.	12-1 a.m.	1-2 a.m.	2-3 a.m.	3-4 a.m.	4-5 a.m.	5-6 a.m.	6-6.30 a.m.	
<i>Aedes africanus</i> ...	6	89	7	1	—	—	1	—	—	2	—	—	8	108
„ <i>luteocephalus</i> ...	7	30	1	1	1	—	—	—	—	—	—	—	1	34
„ <i>irritans</i> ...	8	45	5	1	1	4	1	—	—	—	2	2	1	62
„ <i>nigricephalus</i> ...	5	14	8	2	4	2	1	—	2	2	—	3	—	38
„ <i>lineatopennis</i> ...	4	1	1	2	—	1	—	—	—	1	1	—	—	7
„ <i>vittatus</i> * ...	—	6	5	5	—	3	—	1	1	—	—	—	—	21
<i>Mansonia africana</i> ...	9	174	201	272	253	183	131	176	160	123	156	184	51	2,064
„ <i>uniformis</i> ...	10	72	40	59	59	36	25	37	53	35	48	33	30	527
<i>Anopheles hargreavesi</i> †	7	15	33	68	54	49	56	49	45	25	22	24	19	459
„ <i>mauritanus</i> §	7	17	6	12	7	8	2	2	5	6	5	9	2	81
„ <i>costalis</i> ...	9	3	5	13	34	39	53	52	74	69	34	35	8	419
<i>Culex thalassius</i> ...	5	4	2	3	4	3	4	3	10	3	9	10	2	57
„ <i>tritaeniorhynchus</i>	5	5	6	5	2	4	3	1	2	9	9	2	1	49
„ spp. (<i>pipiens</i> group)	9	11	16	11	7	4	5	1	6	13	4	8	3	89
„ <i>nebulosus</i> ...	5	—	1	3	—	—	—	—	—	2	—	2	4	12
„ <i>consimilis</i> ...	5	20	9	8	12	12	14	6	3	5	4	1	2	96
„ <i>quasigelioides</i> ...	4	8	2	2	1	2	1	—	3	3	—	—	—	22
<i>Mucidus mucidus</i> ...	4	—	2	—	1	1	1	1	—	—	1	1	1	9
Unidentified and miscellaneous‡	—	2	—	3	—	—	2	1	2	3	1	3	—	17
Total ...													4,171	

* Results secured in one all-night catch made in Ibadan.

† Includes probably about five *An. moucheti* var. *nigeriensis*.

§ Varieties *paludis* and *ziemanni* only, *paludis* being much the more common.

‡ Includes, besides five unidentified mosquitos, *Aedes aegypti* 1, *Aë. punctothoracis* 3, *Aë. albocephalus* 1, *Mansonia annetti* 1, *Anopheles pharoensis* 3, and *An. funestus* 3.

However, certain indirect evidence may be presented. In a fairly extended series of observations we noted that both of these species appeared to be equally abundant in the bush well away from villages and at the edges of these villages. Their abundance is roughly correlated with that of their chief breeding-place, tree-holes. This may be taken to indicate that they do not go far in search of human blood, but take what they can get from people passing by. In the villages of southern Nigeria the only animals commonly present are goats, dogs, and chickens. Man is much the largest potential source of blood. In the bush there are usually only birds, reptiles, a few mammals, and the people who travel along the paths between the villages and farmhouses.

It is entirely probable that these two species secure blood from the source most readily available. If they are near human beings, they probably take most of their blood-meals from them. For those which breed at a distance from human habitations wild birds would seem to be the most likely source of blood-meals.

That *A. africanus* has a greater preference for human blood than *A. luteocephalus* is suggested but not proved by the fact that our catches in the vicinity of Lagos included larger numbers of adults of the former species in spite of the fact that the production of the latter species has been shown to be greater (Table VI).

TABLE VI.

Relative Abundance in Lagos and Ibadan of the Larvae of the tree-hole-breeding Species of Aedes which are experimental Vectors of Yellow Fever.

Species	Lagos*		Ibadan†	
	Number	Per cent.	Number	Per cent.
<i>A. luteocephalus</i> ...	6,220	50.7	144	14.5
<i>A. africanus</i> ...	224	1.8	3	0.3
<i>A. simpsoni</i> ...	1	0.01	1	0.1
<i>A. stokesi</i> ...	602	4.9	7	0.7
Other species ...	5,238	42.6	831	84.4
Total ...	12,285	100.0	986	100.0

* Data taken from L. H. Dunn.²

† Data taken from unpublished notes of Dr. H. W. Kumm.

Aedes (Stegomyia) simpsoni.

Larvae of this tree-hole-breeding species is rare in Lagos² and Ibadan (Table VI). Not a single adult was taken in our catches either inside the houses or out-of-doors.

Aedes (Stegomyia) vittatus.

Geographical distribution.—Throughout the portions of Nigeria where there is surface rock this species is very common, but it is practically absent from the vicinity of Lagos because of the absence of the rock-pools which are its chief breeding-place. Among the mosquitos from Lagos examined during the year occupied by this study, we found only one *A. vittatus*, a female taken in a night catch.

Breeding-places.—Among larvae taken from tree-holes in Ibadan by our colleague, Dr. A. W. Burke, we identified a few *A. vittatus*. They were found much more commonly in rock-holes, however.

Time of feeding.—With the assistance of Dr. Burke, we secured data regarding the time of feeding of *A. vittatus*, from observations made in Ibadan in the vicinity of rock-holes in which the species was breeding. These data are not as conclusive as

those for other species regarding which we have made more observations. However, like other species of the genus *Aedes*, *A. vittatus* appears to be crepuscular in its time of activity (Table V).

Our data are insufficient to permit us to draw any conclusions as to the place of activity or preferred blood-meal of this species.

TABLE VII.

Results of Standard Night Catches summarised to show Variations in the Density of Aedes africanus and A. luteocephalus. The catches were made at two places in Mushin in the Vicinity of many Tree-holes, October 1930 to September 1931.*

Month	Rainfall in inches	No. of catches	Station M7				No. of catches	Station M4			
			Mean no. of females taken per catch			All mos- quitos		Mean no. of females taken per catch			All mos- quitos
			Aedes					Aedes			
			afric.	luteo.	Total			afric.	luteo.	Total	
1930											
July ...	22.54	0					0				
August ...	1.12	0					0				
Sept. ...	4.23	0					0				
Oct. ...	8.90	4	25	12	37	56	0				
Nov. ...	1.37	3	61	16	77	105	3	27	10	37	46
Dec. ...	0.64	2	9	2	11	26	0				
1931											
Jan. ...	2.00	2	1	1	2	44	3	1	0	1	29
Feb. ...	2.05	2	3	2	5	20	2	1	1	2	20
March ...	3.45	2	7	5	12	32	2	0	3	3	33
April ...	4.60	0					0				
May ...	7.69	1	4	6	10	16	1	6	9	15	22
June ...	11.75	1	47	14	61	74	1	6	7	13	15
July ...	14.76	1	25	44	69	70	1	15	12	27	27
August ...	2.53	2	27	3	30	35	2	46	10	56	67
Sept. ...	13.35	2	8	2	10	11	2	0	1	1	2

* A bush village near Lagos.

† The amount of rainfall was measured at Yaba, which is $1\frac{1}{2}$ miles distant from Mushin.

Aedes (*Aëdimorphus*) *stokesi*.

The data in Table VI show that in both Lagos and Ibadan the production of *A. stokesi* in tree-holes, which are its principal breeding-places, is greater than that of *A. africanus*. In the published reports of house-captures of mosquitos in West Africa, *A. stokesi* appears to have been taken even more rarely than *A. luteocephalus* and *A. africanus*. Not a single specimen was obtained in our catches inside human habitations. In our entire series of night catches only eight females in the act of biting were taken on six different occasions. Seven of these were taken in the early period and

one during the later period, suggesting that *A. stokesi* also has a crepuscular period of activity. We believe that the rarity with which we took *A. stokesi* biting in places where it had previously been shown to breed in considerable numbers is very strong evidence that its preferred blood-meal is not human blood (Table X).

***Aedes* (*Aëdimorphus*) *irritans*.**

Breeding-place.—The preferred breeding-place of this species is in crab-holes along the edge of salt or brackish water. However, the number of adults of this species taken at Ibadan and at places near Lagos, which are well beyond its flight range, leads us to think that it breeds very frequently in other natural waters. We did not attempt, however, to find such breeding-places. *A. irritans* was not captured farther inland than Ibadan.

TABLE VIII.
Results of Night Catches made at Kano, during the Dry and Rainy Seasons of 1931.

Species	No. of catches made	Number of mosquitos taken		
		Males	Females	Total
<i>Mansonia africana</i> ...	4 during dry season (January)	4	51	55
<i>Mansonia africana</i> ...	14 during rainy season	19	55	74
<i>Anopheles costalis</i> ...	(July)	1	22	23
<i>Aedes hirsutus</i> ...		0	19	19
<i>Culex</i> spp. (<i>pipiens</i> group)		0	5	5
<i>Anopheles pharoensis</i> ...		0	4	4
<i>Aedes luteocephalus</i> ...		0	1	1
„ <i>lineatopennis</i> ...		0	1	1
Total ...		20	107	127

Abundance.—This species has been found in great numbers inside of houses in Lagos, Accra, and Takoradi (^{3,4} and a personal communication to the author), but its abundance has always been associated with heavy breeding near by. At present it is not found inside of houses in Lagos,¹ probably because of the cumulative effect of the sanitary work which has been done there over a long period of years. In a series of house captures made in Iwonran and other small bush villages situated on the shore of Lagos lagoon close to the numerous crab-holes in which the species was breeding profusely, it was taken relatively rarely (Table I). The failure to find this species indoors in these bush villages may be due to the fact that the females prefer to roost in the vegetation which closely surrounds the villages rather than in the houses. In Lagos there is little or no such shelter available. In an attempt to secure information on the density of adult *A. irritans* out-of-doors, a series of night catches was made at Iwonran during the same season a year later. This density was found to be very high (Table III).

Time of feeding.—The data in Tables III and V show definitely that *A. irritans* is crepuscular in its time of activity.

Our data regarding the place of feeding and the preferred blood-meal of this species indicate that in these respects the species resembles *A. luteocephalus*. *A. irritans* has been found to bite man very frequently out-of-doors, but its preferred blood-meal is not known.

***Aedes* (*Aëdimorphus*) *nigricephalus*.**

This species is very similar to *A. irritans* in all respects except that of gross appearance, but it has been found to be much less common both in the larval and adult forms.^{3,4,5}

In night catches made at Iwonran *A. nigricephalus* was taken in considerably greater numbers than *A. irritans* (Table III), but elsewhere in much smaller numbers (Table XI). Because the species was not taken at places which were not close to salt or brackish water, we believe that its breeding-places are much more restricted than those of *A. irritans*.

Dr. Hayne captured *A. nigricephalus* only very occasionally inside of houses in bush villages, in and around which crab-holes were very numerous (Table I). In a recent series of house captures in Lagos¹ only five adults were taken, four of them in houses in the less well-sanitated portions of the city.

The time of feeding, place of feeding, and preferred blood food of this species appear to be very much the same as are those of *A. irritans*, except that the peak of activity of *A. nigricephalus* is not as sharply defined as that of *A. irritans* (Table V).

TABLE IX.

Further Observations on the Time of Activity of Aedes africanus and A. luteocephalus. Results of Series of three-hour Catches made on successive Nights at Mushin by the same two Boys.

Hour (p.m.)				Number of <i>A. africanus</i> and <i>A. luteocephalus</i> females taken with human bait.						Total
				Sept. 21	Sept. 22	Sept. 23	Sept. 24	Sept. 25	Sept. 26	
7.0-7.30	...	...	...	9		5		6		20
7.30-8.0	...	...	...	2		2		5		9
8.0-8.30	...	...	...	0		2		1		3
8.30-9.0	...	...	...	0		0		0		0
9.0-9.30	...	...	...	0	1	0	Rain	0	0	1
9.30-10.0	...	...	...	0	0	0	Rain	2	0	2
10.0-10.30	...	...	...		0		Rain		1	1
10.30-11.0	...	...	...		0		0		1	1
11.0-11.30	...	...	...		2		0		2	4
11.30-12.0	...	...	...		2		0		2	4
Total	...	...	...	11	5	9	0	14	6	45

A. africanus 31, *A. luteocephalus* 14.

Aedes (Banksinella) punctocostalis.

This species is confined to West Africa,⁶ but a study of the literature indicates that it is rare in southern Nigeria. Philip, however, reared about 100 females from larvae which he found near Lagos. We did not take a single *A. punctocostalis* either in our night catches or in our house captures. We believe, therefore, that in the vicinity of Lagos *A. punctocostalis* rarely, if ever, bites man, but we are unable to state whether this is because of its rarity or its lack of desire for human blood.

Aedes (Banksinella) lineatopennis.

We found this species to be rather rare in the vicinity of Lagos, and we have therefore little information to present regarding it. The species was captured only occasionally inside of houses, and then only in houses close to dense vegetation; out-of-doors it was taken biting only during the rainy season. Like most of the other *Aedes*, it appears to be crepuscular in its activity (Tables V and XI).

Eretmopodites chrysogaster.

Among several hundred adults which we reared from *Eretmopodites* larvae taken in Ibadan and in the vicinity of Lagos, we found only *E. chrysogaster*, indicating that this species is the most common member of the genus in the cocoa-producing region of south-western Nigeria.

Breeding-places.—In our experience the preferred breeding-places of this species are the small collections of water which are to be found in fallen leaves lying in densely shaded places on moist ground. Practically without exception, when water was found in fallen leaves, *E. chrysogaster* larvae were observed in the water. There is a heavy production of this species in cocoa groves during the rainy season. The cocoa trees provide the necessary shade, and their fallen leaves commonly hold water, even when broken cocoa-pods lying very close by under identical conditions are dry. The larvae commonly occur in small numbers in these collections of water and are usually in markedly different stages of development.

Abundance inside of houses.—In all of our and Dr. Hayne's combined house captures only one *E. chrysogaster* was taken, but it must be admitted that the expectation of taking this species was not great in most instances.

Abundance outside of houses.—A special series of forty-five night catches was made in Ibadan and in the vicinity of the village of Ikeja, near Lagos, in cocoa groves where the production of *E. chrysogaster* was great (Table IV). In this series of catches only one *E. chrysogaster* was taken biting man. We believe this to be conclusive evidence that this species bites man only rarely during the first three hours after sunset. Furthermore, no *E. chrysogaster* were included among the 7,640 mosquitos taken in the seventeen all-night catches, but only a few of these night catches were made in places where this species was known to be breeding.

In spite of the fact that Bauer⁷ observed that the female *E. chrysogaster* in captivity would readily bite man or monkeys when no other food was offered and would lay viable eggs after such feedings, we believe that the evidence we have presented warrants the conclusion that this species does not bite man in nature.

Mansonia (Mansonioides) africana.

Breeding-places.—It is difficult to determine the breeding-places of this and of other species of *Mansonia* because of the peculiar adaptation of the siphon of the larva, which enables it to pierce the rootlets of various aquatic plants and obtain air without coming to the surface of the water. The larvae are commonly found on the roots of water lettuce (*Pistia stratiotes*). Recently Schwetz⁸ found the larvae in the Belgian Congo on the roots of two other plants, *Impatiens irvingii*, Hook., and *Hydrolea glabra*, Schum.

Because of the large numbers of adults which we have captured in regions free from *Pistia*, even taking into consideration the long flight range of this species, we are convinced that in the vicinity of Lagos the larvae are developing on the roots of other plants. We made an extensive search for such plants, but failed to find them.

Abundance.—In Nigeria *M. africana* has long been known to be widespread and very abundant both inside and outside of houses. However, on Lagos Island, upon which the main part of Lagos is situated, Beeuwkes *et al.*¹ did not capture a single individual. In Ikoyi (the European reservation of Lagos) we took a few individuals during the rainy season of 1931. In contrast to this, both *M. africana* and its congener *M. uniformis* were exceedingly abundant in parts of Ebute Metta, a suburb of Lagos on the mainland. The particular place at which we found *M. africana* to be most abundant was in and near the swamps which are close to the houses of the Railway reservation. The greatest density of this species was at the edge of the swamps.

In Ibadan we found large numbers of larvae of *M. africana* on the *Pistia* which grows in abundance on some of the streams and swamps intersecting the city, but the density of adults inside the houses in the city could not be correlated with the distribution of *Pistia*.

Extended studies have recently been made of seasonal variations in the abundance of *M. africana* inside of houses in four cities in Nigeria.¹ We have made further observations of the seasonal variation of this species in the vicinity of Lagos. In Table XII are summarised the results of a series of house captures made at Station 1 during the long dry season of 1930-31. The abundance of *M. africana* diminished greatly as the dry season progressed, but it should be noted that Station 1 was located about half a mile from the nearest probable breeding-place of *M. africana*.

TABLE X.

Summary of Data regarding Species which were very rarely taken biting Man.

Species	No. of times taken	Number of females taken biting		
		First 90 min.	Second 90 min.	Total 3 hours
<i>Aedes stokesi</i> ...	6	7	1	8
.. <i>apicoargenteus</i> ...	3	0	3	3
.. <i>longipalpis</i> ...	1	1	0	1
.. <i>domesticus</i> ...	2	2	0	2
.. <i>argenteopunctatus</i>	2	1	1	2
<i>Ficalbia</i> sp.* ...	1	2	0	2
<i>Uranotaenia annulata</i> * ...	7	5	6	11
.. <i>mashonaensis</i> *	2	1	1	2
<i>Mimomyia splendens</i> * ...	2	1	1	2
<i>Culex rima</i> † ...	1	0	1	1

* In the early part of the work no attempt was made to identify *Uranotaenia* spp. and similar small mosquitos, hence these totals are somewhat smaller than they should be.

† Two *C. rima* were also taken in an all-night catch, between midnight and 2 a.m.

Our night catches to determine seasonal variations in abundance were made on a more extended scale, over a period of nine months at a group of five stations at which *M. africana* was abundant. The results are summarised in Table XIII. No great variation in abundance of *M. africana* was noted except during April when the number taken per catch dropped considerably at all five stations. Unfortunately, it was not possible to make catches at these stations during the months of greatest rainfall.

Time of feeding.—Our observations have confirmed Philip's statement⁹ that during the day one can visit swamps known to harbour great numbers of *M. africana* without being bitten by these mosquitos except occasionally. The females begin to bite about sunset and reach their maximum activity about two hours later. They continue their activity throughout the night and stop biting rather suddenly about dawn (Table V). We found no difficulty, however, in inducing non-gravid females in captivity to engorge during the day either upon man or monkeys. The females which are found inside of houses during the day are usually fully engorged and appear to be completely inactive.

Place of feeding.—The evidence already cited, indicates that *M. africana* not only bites man out-of-doors with great frequency but also readily invades houses in search of human blood.

Preferred blood meal.—*M. africana* is everywhere recognised as a pestiferous mosquito because it attacks man so readily. Davis & Philip¹⁰ using the precipitin test, found that all of the females which they took inside of houses had engorged on man. There is no doubt that human blood is the preferred blood meal of *M. africana*.

Mansonia (Mansonioides) uniformis.

This species is likely to be confused with *M. africana* because of its great similarity in appearance and manner of biting. Furthermore, the two species often occur together in nature.

TABLE XI.

Additional Data on the Time of Activity of the Females of certain Species of Mosquitos.

Species	No. of standard night catches made	Number of females taken.		
		First 90 min.	Second 90 min.	Total 3 hours
<i>Anopheles mauritanus</i> ...	100	93	49	142
„ <i>pharoensis</i> ...	10	3	10	13
<i>Aedes irritans</i> ...	50	532	75	607
„ <i>nigricephalus</i> ...	50	276	107	383
„ <i>punctothoracis</i> ...	16	24	2	26
„ <i>hirsutus</i> * ...	6	7	12	19
„ <i>lineatopennis</i> * ...	25	30	13	43
<i>Culex thalassius</i> ...	25	28	23	51
„ <i>tritaeniorhynchus</i> ...	25	101	52	153
„ spp. (<i>pipiens</i> group) ...	50	112	46	158
„ <i>nebulosus</i> ...	15	12	7	19

* Taken only during the rainy season.

Geographical distribution in Nigeria.—In our catches *M. uniformis* was taken in large numbers in the environs of Lagos but never in the city itself. During the rainy season it was also captured in small numbers in places as far as twenty miles inland from Lagos, but never in Ibadan. Beeuwkes *et al.*¹ failed to take a single specimen in Ibadan, Kano, or Zaria, and we believe the species to be absent from these large interior cities. On the other hand, it has been identified by Edwards¹¹ in at least ten far inland places in Nigeria, all of which have a small human population. In Nigeria the range of *M. uniformis* appears to be very similar to its range in the Gold Coast near by, where Macfie & Ingram⁴ found it to be abundant along the coast, much less common in the rain-forest belt, and absent in the far-inland, semi-arid regions.

Breeding-places.—The immature stages of this species are much more elusive than those of *M. africana*. In spite of the wide distribution of the species and its great density in many places, its immature stages appear to have been taken only twice: once near Singapore on the roots of grass¹² and once in Java on *Pistia*.¹³ In the vicinity of Lagos an extensive search for the larvae was made in various types of swamps and marshes in and near which the adults were taken, literally in thousands, but not a single larva was found. More than 1,000 adults reared from *Mansonia* larvae which had been taken from the roots of *Pistia* growing near Lagos and in Ibadan, were all found to be *M. africana*. We believe that in Nigeria *M. uniformis* breeds not on *Pistia* but in the swamps in which we captured large numbers of adults.

Abundance.—The great abundance of *M. uniformis* in the environs of Lagos has already been noted. Like *M. africana*, it is equally abundant inside and outside of human habitations.

The summaries in Tables XII and XIII show the results of our observations on seasonal variations in the abundance of *M. uniformis* in the vicinity of Lagos. The house captures were made during the dry season, and the results indicate that the species tends to increase in numbers as this season progresses. However, many potential breeding-places still existed near Station 1 all through the dry season of 1930-31, in spite of the fact that there was little rainfall.

The night catches were begun in the middle of the dry season and were continued through the following rainy season. From January on through April the swamps near which these catches were made were slowly drying but never became completely dry. *M. uniformis* was observed to be exceedingly abundant during the middle of the dry season but to have greatly decreased in numbers by the end of this season. During the remainder of the period of observation, its abundance was about the same as at the end of the dry season. Throughout the entire period it was relatively abundant in comparison with other mosquitos.

TABLE XII.

Density Indices* of *Mansonia africana*, *M. uniformis*, and other mosquitos at Station 1† during the Dry Season of 1930-31.

Date of catches	Number of catches	Density indices of adult mosquitos caught			
		Female <i>M. africana</i>	Female <i>M. uniformis</i>	Female <i>Anopheles</i> spp.	All mosquitos, male and female
1930					
Nov. 1-Dec. 27	53	50	73	283	590
1931					
Jan. 4-21	16	20	99	148	487
March 2-30	23	8	118	47	513
Whole period	92	34	88	200	554

* The density index of adult mosquitos is defined as the number of mosquitos captured per 100 rooms.

† Station 1 consisted of five unscreened sleeping rooms in two houses on the Commission compound at Yaba, five miles inland from Lagos.

We found the habits of *M. uniformis* with regard to time of feeding and place of feeding to be almost exactly the same as those of *M. africana*. There seems to be no doubt that the preferred blood-meal of *M. uniformis* is human blood.

A few observations made on the egg-laying habits of this species indicated that from four to six days were required for the eggs to develop to maturity after a full blood-meal. It was found difficult to induce *M. uniformis* females to oviposit in captivity. When occasionally they did, they fed readily upon man a second time. The eggs of *M. uniformis* are similar in appearance to those of *M. africana*.

Culex thalassius.

Although this species is distributed over a wide area in tropical and South Africa, its range appears to be everywhere restricted to a relatively narrow zone along the coast.^{4,14} The species is not common now in the vicinity of Lagos.¹ We found it rarely inside of houses, and we took it biting, in small numbers, only on or near the shores of salt or brackish bodies of water.

Time of feeding.—The data in Table V show that *C. thalassius* is active throughout the night. The results of the standard night catches given in Table III show that

many more females were taken biting in the second ninety minutes than in the first, indicating that they did not reach the peak of their activity until at least two hours after sunset.

Culex spp. (pipiens group).

The *pipiens* group is composed of several different species so closely related that it is difficult, and in some cases impossible, to distinguish the adult females. For this reason we treated the group as a single species. The most common Nigerian members of the group are *C. decens* and *C. univittatus* and some of their varieties (unpublished communication of C. B. Philip).

The data in Table V regarding the time of activity of the *pipiens* group show that it is active throughout the night, with a low peak of activity in the early evening. This crepuscular peak is shown also in the results of the standard night catches, which are summarised in Table XI.

TABLE XIII.

Results of a Series of standard Night Catches summarised to show the Seasonal Variation in the Abundance of Mansonia africana and M. uniformis at five Stations in Ebute Metta during 1931.*

Species	Station	Average no. of females taken in a standard night catch.								
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
<i>Mansonia africana</i>	77	59	30	—	15	40	—	—	25	43
	79	13	21	—	8	54	—	—	10	47
	81	16	32	—	8	15	—	—	10	64
	83	60	106	—	22	83	—	—	36	73
	85	19	13	—	4	15	—	—	26	6
	All	33	40	—	11	41	—	—	21	47
<i>Mansonia uniformis</i>	77	159	111	—	18	12	—	—	26	16
	79	27	51	—	17	7	—	—	0	3
	81	68	85	—	26	11	—	—	10	13
	83	115	193	—	8	54	—	—	12	37
	85	43	74	—	12	16	—	—	17	16
	All	82	103	—	16	20	—	—	13	17
	Rainfall (inches)	2.00	2.05	3.45	4.60	7.69	11.75	14.76	2.53	13.35

* Railway reservation, a suburb of Lagos.

Culex nebulosus.

This species is exceedingly abundant in southern Nigeria and breeds prolifically in tree-holes^{2,5} and in the "medicine pots" in houses.^{1,3} In spite of this, we took only nineteen females in 15 out of more than 400 standard night catches (Table XI). Furthermore, very small numbers of females were taken during the all-night catches (Table V). These results provide further evidence that *C. nebulosus* rarely bites man and, consequently, that its preferred blood-meal is not human blood.

Anopheles costalis.

Our only observations on this species, which is very important in the transmission of malaria in Africa, concerned its time of feeding. The data in Table V show that *An. costalis* is most active from about midnight to dawn and that it reaches the peak of its activity between 2 and 4 a.m. However, the data in Table II, which are derived from the results of standard night catches made in places at which this species was abundant, show that *An. costalis* frequently bites man earlier in the evening.

Summary.

Almost all of the studies here reported were made in one small region, so that very little new information was secured on the ranges of the species of mosquitos under consideration.

TABLE XIV.

Summary of Findings on the Abundance, Place of Feeding, and preferred Blood-meal of fourteen Species of Mosquitos which are either experimental Vectors of, or are non-lethal to, the Virus of Yellow Fever, Vicinity of Lagos, Nigeria, 1930-31.

Preferred blood meal	Species abundant both inside and outside of human habitations	Species abundant only outside of human habitations	Species abundant only inside of human habitations	Species not abundant either inside or outside of human habitations
Human ...	<i>Mansonia africana</i> <i>Mansonia uniformis</i> <i>Culex thalassius</i>		<i>Aedes aegypti</i>	<i>Aedes simpsoni</i> <i>Aedes punctocostalis</i> <i>Aedes lineatopennis</i>
Probably human		<i>Aedes luteocephalus</i> <i>Aedes africanus</i> <i>Aedes irritans</i> <i>Aedes nigricephalus</i> <i>Aedes vittatus*</i>		
Probably not human		<i>Aedes stokesi</i> <i>Eretmopodites chrysogaster</i>		

* *A. vittatus* is rare in the vicinity of Lagos, but is abundant in the interior of Nigeria.

Our investigations regarding breeding-places were limited to a few species. *Aedes vittatus* was found occasionally breeding in tree-holes in Ibadan. *Aedes irritans* adults were taken at Ibadan, which is so far inland that this species must sometimes breed in places other than crab-holes at the edges of salt or brackish water. We did not, however, find the larvae of this species at Ibadan. The favourite breeding-place of *Eretmopodites chrysogaster* was found to be small collections of water in fallen leaves (especially those of cocoa trees) lying in moist and densely shaded places. Because of the abundance of *Mansonia africana* in places practically free from *Pistia*, we conclude that in the vicinity of Lagos it must breed abundantly on other plants. The long flight range of this species was taken into consideration in arriving at this conclusion. An extensive search failed, however, to reveal these plants. *M. uniformis*, also abundant in the vicinity of Lagos, does not breed there upon *Pistia*, but an extensive search failed to reveal its breeding-place.

A summary of our findings regarding the abundance, place of feeding, and preferred blood-meal of the fourteen species of West African mosquitos which are of potential importance in the transmission of yellow fever is presented in Table XIV.

Similar data were secured for two other species abundant in southern Nigeria, namely, *Culex nebulosus* and *Culex* spp. (*pipiens* group) ; but these data were not included in the table because there is good evidence that these species are not concerned in the transmission of yellow fever. Both species breed abundantly inside and outside of human habitations. The fact that *C. nebulosus* was rarely taken out-of-doors biting man is further evidence that its preferred blood-meal is not human blood. In southern Nigeria, however, the *pipiens* group, the members of which we did not attempt to differentiate because of the great difficulty in distinguishing the adult females, do bite man fairly frequently.

Extended observations on the seasonal variations in abundance were made in the case of only four species : *Aedes africanus*, *A. luteocephalus*, *M. africana* and *M. uniformis*. *Aedes africanus* and *A. luteocephalus* were found to show, as was to be expected, great seasonal variation in the abundance of adults. At certain places they ranged from the most abundant of all species during and just after the rains to rare species at the height of the dry season. The abundance of *M. africana* remained fairly constant throughout the year except for a marked drop during one month at the end of the dry season. The abundance of *M. uniformis* showed more variation. It was at its highest, and over twice that of *M. africana*, in the middle of the dry season, and decreased to about one-tenth of its maximum abundance and to about one-third of that of *M. africana* at the end of the rainy season.

Our findings regarding the time of activity of the species which bite man frequently out-of-doors may be summarised as follows : no species are active during the day-time ; the Aëdines are crepuscular ; and the non-Aëdines are nocturnal. Some of the non-Aëdines, including *M. africana*, *M. uniformis* and *C. thalassius*, are rather uniformly active throughout the night ; others, particularly *Anopheles costalis* and *An. hargreavesi*, have a peak of activity at midnight or later ; and still others, like *An. mauritanus* and *Culex* spp. (*pipiens* group), have a crepuscular peak of activity.

Acknowledgments.

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ON THE BIOLOGY OF SOME SPECIES OF *LONGITARSUS* (COL., CHRYSOM.) LIVING ON RAGWORT.

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1. Introduction.

It appears from the literature that the species of *Longitarsus* recorded from ragwort (*Senecio jacobaea*) or its ally the groundsel (*S. vulgaris*), are *L. dorsalis*, F., *L. suturellus*, Duft., *L. senecionis*, Bris., *L. jacobaeae*, Wat., *L. ochroleucus*, Marsh., and *L. gracilis*, Kutsch.; the last named species is also recorded by Bedel from *Tussilago*. In addition *L. succineus*, Foudr., has been associated with various composites, such as *Eupatorium cannabinum* and *Chrysanthemum* spp. but, apparently, never before with *Senecio*.

During the seasons 1928-29 the author was engaged in work on *Tyria jacobaeae* for ragwort control in New Zealand and this entailed frequent visits to the "Brecklands" of south-western Norfolk for the collection of its pupae, etc., for transit to New Zealand. It was on these occasions and less frequently since, when opportunity offered, that the following observations on some *Longitarsus* beetles living on ragwort were made. Not only because of the interest attached to knowledge of the larval stages of such a variable genus as *Longitarsus*, but because also of its bearing on the insect-plant relations of *Senecio jacobaea*, this note has been written.

In all, some seven species of *Longitarsus* were met with, viz., *L. jacobaeae*, *L. dorsalis*, *L. succineus*, *L. gracilis*, *L. exoletus*, L., *L. luridus*, Scop., *L. melanocephalus*, All., but of these the last three were not associated with *Senecio*. Of the rest, and it is with them that this note deals, *L. jacobaeae*, *L. gracilis* and *L. succineus* are stated to be generally abundant throughout the kingdom, while *L. dorsalis* is not common and apparently confined to the southern half of England.

I have pleasure in acknowledging help I have received from Mr. J. R. le B. Tomlin and Mr. H. Britten of the Manchester Museum in confirming the identifications.

2. *Longitarsus jacobaeae*, Wat.

This is one of the most abundant of the *Longitarsus* species and is stated to occur generally throughout the kingdom. It is well distributed over the ragwort areas of the "Brecklands" of south-western Norfolk. Bedel gives its distribution as "river banks, littoral cliffs abundant on the Channel coasts, less frequent in the interior and rather generally confined to the lengths of the great river-beds, e.g., Seine and Marne." The "Brecklands" are, however, essentially dry regions.

Fowler recognises a darker form var. *rufescens* varying from ferruginous to a clear red in exceptional cases; this variety was occasionally present.

Food-plants.

Ragwort (*Senecio jacobaea*) appears to be the only recorded food-plant. In the laboratory the beetles were fed from the beginning of August to the end of November on the following plants. At the end of this period all survived on *S. jacobaea*, 80 per cent. on *S. aquaticus*, 50 per cent. on *S. sylvaticus*, 30 per cent. on *S. vulgaris*, 50 per cent. on cultivated sunflower (*Helianthemum* sp.), none on the aster (*Callistephus* sp.), Michaelmas daisy (*Aster* sp.), marguerite (*C. leucanthemum*) and golden rod (*Solidago virgaurea*). Of the last three plants, the foliage of Michaelmas daisy and marguerite were only slightly nibbled, the other was untouched.

Life-history.

The new generation of beetles was first seen at the end of July, the numbers reaching a maximum in late August. After emergence copulation takes place at once and egg-laying follows soon afterwards. The first eggs were seen in mid-August. They are laid in the soil. Those laid in late summer hatch in about a month or under, but later ones do not hatch till the following spring, so that the winter is passed in both egg and larval stages. Development goes on at the expense of the root system of the host, but although the larvae may be numerous, the growth of the plant is not noticeably affected. Fully grown larvae occur from June onwards, pupation follows in the usual earthen cell, lasts for a fortnight to three weeks, and the newly emerged adults, as stated above, begin to be seen during the latter half of July. There appears to be but one generation a year.

It is notable that *L. jacobaeae*, by passing the winter in the developmental stages, differs from the majority of flea-beetles studied by the writer. In this respect, however, it agrees with *Psylliodes chrysocephala* (cabbage-stem flea-beetle). This fact has a bearing on its effectiveness as a controlling agent of the growth of its host-plant. It means that the appearance of the beetles does not coincide with that of the young ragwort plants. They are well established by the time of the mass emergence of the beetles and so escape the early attack that is so devastating in the case of the Cruciferae-eating flea-beetles.

Description of the Developmental Stages.

The egg of *L. jacobaeae* is elongate, oval, with rounded ends, and measures 0.66 mm. long and is rather less than half as broad. It is yellow in colour, becoming darker before hatching. Its surface sculpturing is similar to that of other flea-beetle eggs and consists of a network of polygonal pits (fig. 1).

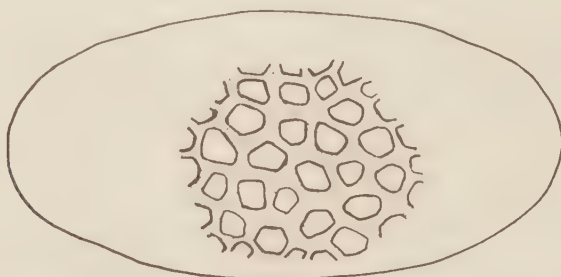


Fig. 1. *L. jacobaeae*, Wat.: egg in outline ($\times 95$) with part of surface highly magnified ($\times 475$) to show sculpturing.

The young larva, which bites its way out of the egg-shell—a leisurely proceeding taking some hours, is about 1.5 mm. long and 0.25 mm. in width. The head, prothoracic shield and anal plate are dark greyish brown, the head being darkest. The legs and segmental plates faintly brown. The arrangement of the segmental plates and setae is essentially the same as in the fully grown larva, but relative to the size of the young larva the segmental plates are much larger than in later life, so that they almost completely cover the segments. The head is also proportionately large.

The fully grown larva is some 6 mm. long and just over 1 mm. across. It is white in colour, elongate in form, similar to that of *L. dorsalis* (fig. 7) but somewhat less slender and more robust. The head-capsule is dark brown, anal plate and prothoracic shield brown, and legs light brown. The three short stumpy pairs of thoracic legs shows the usual five segments. The first eight abdominal segments are similar, the

ninth carries the anal plate above, and beneath the anal proleg containing the anal opening on the reduced tenth segment. One thoracic and eight abdominal spiracles are present.

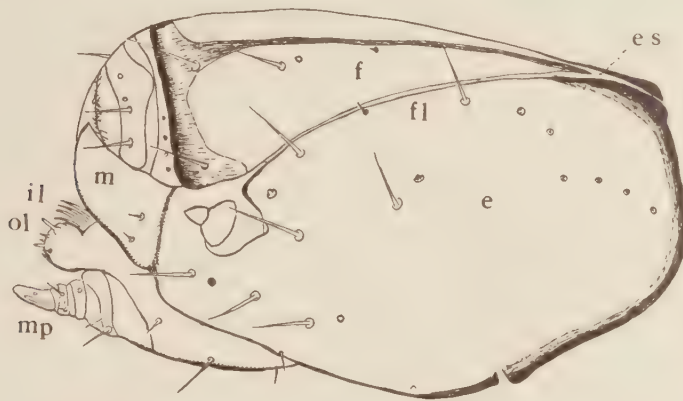


Fig. 2. *L. jacobaeae*, Wat.: side view of head-capsule to show arrangement of setae, $\times 190$; *mp*, maxillary palp; *ol*, outer lobe of maxilla; *il*, inner lobe; *m*, mandible; *f*, frons; *fl*, fronto-lateral suture; *e*, epicranium; *es*, epicranial suture.

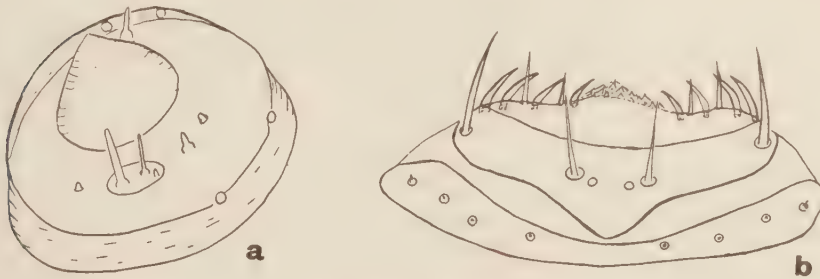


Fig. 3. *L. jacobaeae*, Wat.: *a*, right antenna from above—schematic, $\times 900$; *b*, labrum and clypeus, $\times 475$.

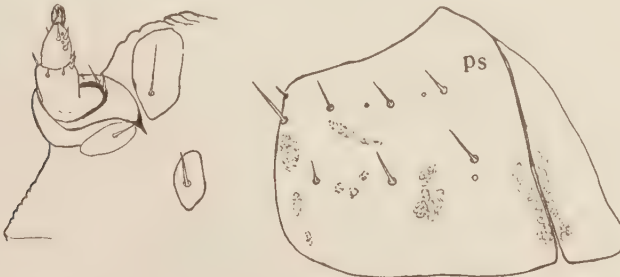


Fig. 4. *L. jacobaeae*, Wat.: side view of prothorax, $\times 120$; *ps*, prothoracic shield.

The head-capsule (fig. 2) is well chitinised above, weakly beneath, and shows the fronto-lateral and epicranial sutures and other usual features of flea-beetles. The arrangement of the setae is seen from the figure. The sensory organs of the antennae are shown in schematic form in fig. 3, *a*; the labrum in fig. 3, *b*. The

strong, five-toothed mandibles bear two strong spines (occasional specimens have three) on their inner surface above the molar area and externally bear two setae; the maxilla with its well armed galea and lacinia and segmented palps presents no unusual features. Dorsally the prothoracic shield (fig. 4) covers the prothorax; it carries an anterior row of 8 and a posterior row of 6 setae, and has a median suture. Fig. 5A shows the arrangement of the segmental plates on the meso-thorax which,

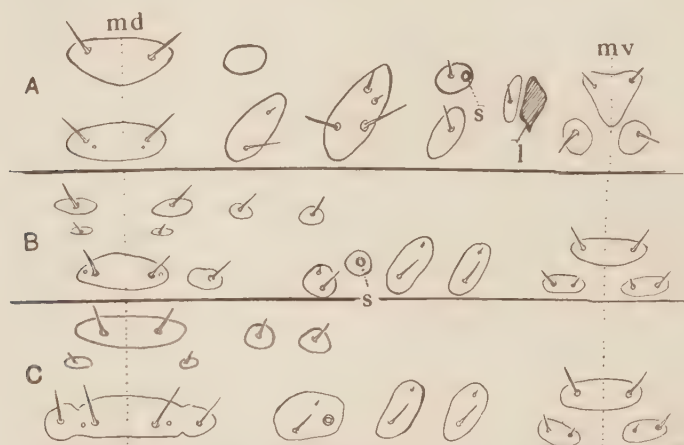


Fig. 5. *L. jacobaeae*, Wat.: map of arrangement of chitin plates and setae on A, meso-thorax; B, abdominal segments I-VII; C, abdominal segment VIII; *md*, mid-dorsal line; *mv*, mid-ventral line; *l*, leg; *s*, spiracle.

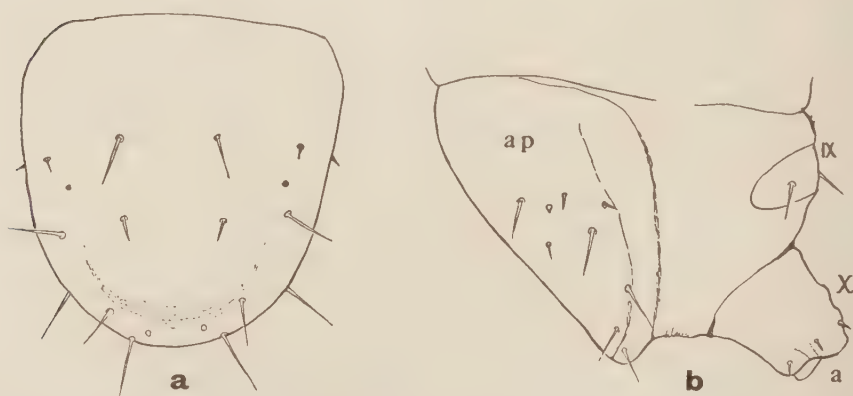


Fig. 6. *L. jacobaeae*, Wat.: a, dorsal view of anal plate; b, side view of posterior end of larva, $\times 80$; *ap*, anal plate; *a*, anus; IX and X, ninth and tenth abdominal segments.

except for the presence of the spiracle, is the same as that on the metathorax; fig. 5B that on abdominal segments 1-7; fig. 5C that on the 8th abdominal segment. The anal plate (fig. 6, a) is broad, rounded and slightly depressed apically.

A large number of larvae of *L. jacobaeae* have been examined under high power, and it appears that the structural characters outlined in this note are essentially

constant. The same applies to *L. dorsalis*, but in this case fewer larvae have been compared. One point may, however, be mentioned. In sorting them over, the larvae of *L. jacobaea* fell into two groups of approximately equal numbers depending on a slight difference in the shape of the anal plate. This in the one case was of a narrower more elongated form, in the other a slightly broader type. It is possible that this may be a sexual difference.

The Pupa and Prepupa.

The prepupa assumes the normal recurved shape and builds up the earthen cell in which pupation takes place.

The pupa is white and of the usual flea-beetle form. The chaetotaxy is as follows : Head, 6 setae, 3 in a vertical line between the eyes on each side of middle line ; often the median seta is duplicated. Thorax, 10 setae ; 2 pairs median, 1 pair antero-lateral, 1 pair postero-lateral, 1 pair medio-lateral near lateral margin ; the latter setae may be duplicated. Meso- and meta-thorax, 4 setae each in a transverse line. Abdomen 8 setae in a transverse line, the external setae on each side (pleural) below the stigma. The 7th abdominal segment shield-shaped ; 8th and 9th reduced, the latter bearing the brown anal horns. Legs with 2 setae, the femur at the femoro-tibial bend.

3. *Longitarsus dorsalis*, F.

This is a distinctive species which appears to have no variations, and consequently there is no confusion about the nomenclature.

Food-plants.

Senecio jacobaea and *S. vulgaris* are given by Fowler, *S. erucifolius* by Foudras, *S. erucifolius*, *S. vulgaris* and perhaps also *Erigeron canadense* by Bedel.

It was found by the writer in a field of ragwort surrounded by woodland on the edge of the " Breckland " district of south-west Norfolk in very large numbers ; on the more open " Brecks " of the neighbourhood it still occurred but was much more thinly distributed. *L. jacobaeae* was also present later in the year in the same field, but in distinction from *L. dorsalis* this species occurred in great numbers over most of the " Breckland " area.

L. dorsalis was not taken in the field on plants other than ragwort, but in the laboratory it was fed on related plants for some four months. At the end of this period all the beetles had survived on *Senecio vulgaris*, *S. sylvaticus*, and *S. aquaticus*, 90 per cent. on sunflower (*Helianthemum* sp.), 75 per cent. on marguerite (*C. leucanthemum*), 50 per cent. on a cultivated Michaelmas daisy (*Aster* sp.), and 25 per cent. on golden rod (*Solidago virgaurea*).

Life-history.

Adults of *L. dorsalis* were first observed in April and could be found on the plants till July, by the end of which month they had practically all died off. Egg-laying had already begun towards the end of April and continued throughout May and June, the eggs, as with *L. jacobaeae*, being deposited in the soil. Half-grown larvae were found in August, full-grown larvae in late August and September, pupae in late September and early October, the mass appearance of the new generation occurring in that month. Unlike *L. jacobaeae*, the winter appears to be passed in the adult stage.

Description of the Immature Stages.

The egg is of similar dimensions (0.6 mm. \times 0.23 mm.) to that of *L. jacobaeae* and possesses the same type of sculpturing, but is of an orange colour.

The larva (fig. 7) differs from *L. jacobaeae* in two features which easily allow of their separation. First, the anal plate is more pointed and pear-shaped, with a depression at its tip. Second, the dorsal anterior median plates of abdominal segments 1-7 are



Fig. 7. *L. dorsalis*, F.: larva, half-grown, \times 30 (drawn from potash preparation).

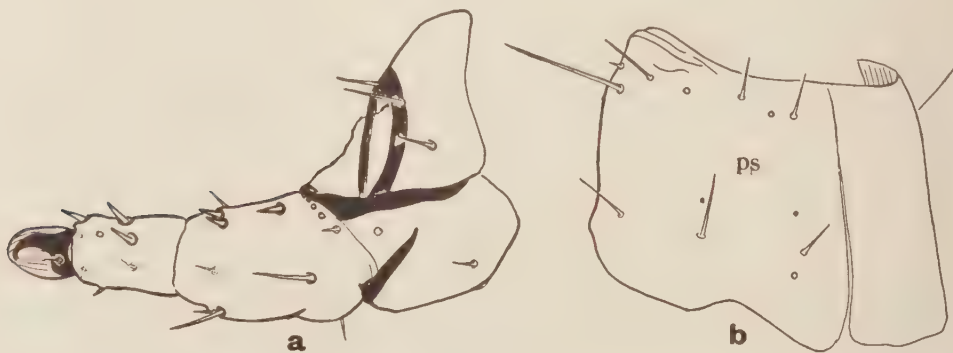


Fig. 8. *L. dorsalis*, F.: a, right prothoracic leg (ventral internal view), \times 295; b, prothoracic shield.

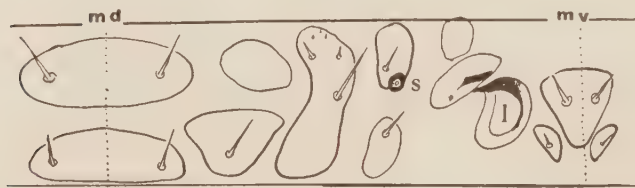


Fig. 9. *L. dorsalis*, F.: arrangement of setae on mesothorax; md, mid-dorsal line; mv, mid-ventral line; l, leg; s, spiracle.

not divided. These points together with other features of the larva are shown in figs. 8-10. A minor point of difference is in the chaetotaxy of the head-capsule. The median frontal seta is much smaller. The arrangement of the sense-organs on the antennae and the armature of the labrum is identical, however.

So far as my observations go the pupa cannot with certainty be separated from that of *L. jacobaeae*.

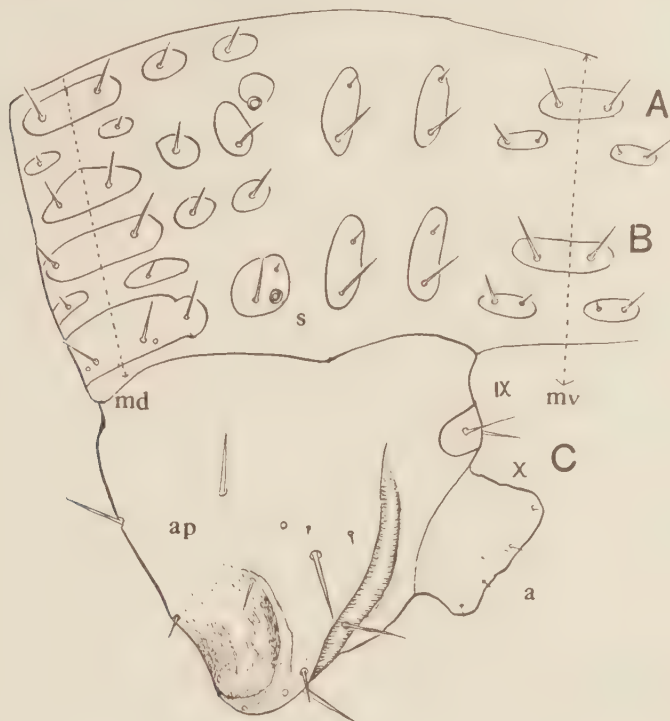


Fig. 10. *L. dorsalis*, F.: arrangement of setae on A, abdominal segments I-VII; B, abdominal segment VIII; C, posterior end of larva (segments IX and X); *md*, mid-dorsal line; *mv*, mid-ventral line; *a*, anus; *ap*, anal plate; *s*, spiracle.

4. *Longitarsus succineus*, Foudr.

This species does not appear in Fowler's Coleoptera, but in the supplementary volume (1913) *L. aeruginosus*, Foudr., is given with the statement that it is the same species as *laevis* of the British Catalogue, the *laevis* of Allard being the same as the *succineus* of Foudras.

L. aeruginosus was established by Foudras, and although Allard makes his *L. laevis* synonymous with it, Bedel treats them as distinct species. On this point Tomlin & Sharp (1912) write:—"This author's discrimination, however, does not appear to us to be very convincing, resting as it does on the difference in character of the apical cilia, which are certainly quite easily abraded; and in the comparative length of the antennae, which differ sexually. Moreover we have had British specimens discriminated as *L. aeruginosus* returned to us by Mr. Bedel himself as *L. succineus*. We therefore cannot escape the conclusion that whether the insect described as *L. aeruginosus* by Foudras is specifically valid or not, the specimens we take in this country on *Eupatorium* (the food-plant of '*L. aeruginosus*') or any other composite are all of one species—*L. succineus* Foudr." It appears therefore that the *L. aeruginosus* of Fowler's supplement does not stand; it would further seem that the description of his *L. laevis*, Duft., in Vol. IV applies to the same insect as the *laevis* of Allard, though Bedel does not regard them as synonyms.

Food-plants.

Heikertinger (1926) records the beetle from *Eupatorium cannabinum* from the end of July to the beginning of September, and from *Chrysanthemum* sp. cult. (? *indicum*) at the end of August. He regards it as an oligophage on composites, perhaps with a narrow choice, and says that although during the summer the insect is one of the commonest of the *Longitarsus* spp. in meadows and hedges, etc., there is still some uncertainty regarding its food-plants. It is found at times in large numbers remote from *Eupatorium* or *Chrysanthemum* on different plants in meadowland. Experiments with food-plants furnish indefinite results. The following composites were sometimes eaten:—*Achillea millefolia* (often refused), *Artemisia vulgaris*, *Tussilago farfara*, and *Cirsium arvense*; plants of other families often eaten were, *Symphytum officinale*, *Salvia nemorosa* and *pratensis*, *Thymus serpyllum*, *Plantago lanceolata* (preferred), *P. major*, and others. Bedel gives "Friches et coteaux secs; sur diverses Composées, *A. millefolium* (St. Clair-Deville), *Leucanthemum vulgare*, *Artemisia campestris* (Weise)." It is to be observed that Bedel separates his *aeruginosa*, Foudr., and *succinea*, Foudr.; and the former is described from *Eupatorium cannabinum* in summer and autumn, occurring in "lieux herbes très humides."

Though Heikertinger does not appear to recognise the *aeruginosus* of Foudras (regarding it as *succineus*), the difference in the habitat in the two cases seems to indicate that there are two species involved. The habitat of Heikertinger's *succineus* is given as dry.

Tomlin & Sharp are able to confirm Allard's statement that the beetle is common on *Chrysanthemum* in gardens (e.g., in Cheshire). It has been taken on *C. leucanthemum* in Devonshire, and on *Achillea millefolium* in Surrey. These authors say it is sometimes taken on *Eupatorium cannabinum* and is one of the most abundant species throughout the late summer and autumn, its range extending throughout the kingdom.

The writer found it occurring in very large numbers indeed on the ragwort areas of the Norfolk Brecklands, and its only food-plant, so far as could be seen, was *S. jacobaea*. Its life-history is considered with that of *L. gracilis*.

5. *Longitarsus gracilis*, Kuts.

Two varieties of this species are recognised, var. *poweri*, All., with a black suture and var. *nigrothorax*, Hktgr., with a blackish brown thorax. Large forms, as Tomlin & Sharp remark, may be mistaken for small *L. jacobaeae*.

Food-plants.

Heikertinger (1926) gives as its only host-plant *Tussilago farfara* and says that it occurs in fairly moist (halbfeuchtig) places. Fowler, however, records it from *S. jacobaea*, and it was on this plant that it was found in some numbers by the present writer.

Life-histories of L. succineus and L. gracilis.

Heikertinger (*l.c.*) gives the time of appearance and ovipositional periods of both these beetles as more or less coincident—namely in autumn, from September to mid-October.

In the "Brecklands" the adults are found much earlier than this, and already by the end of June oviposition was in progress. The eggs differ in colour, those of *L. succineus* being greenish brown, those of *gracilis* yellowish brown. They are of similar dimensions to those of *L. dorsalis*. The incubation period is from two to three weeks, and eggs were already hatching by the beginning of August. In the field, beetles

were difficult to find in October, but in the laboratory gravid females were still alive. At the same time half-grown larvae were present in the soil both in the field and in experimental pots. It is thus probable that hibernation takes place in the larval and pupal stages, but whether also in the adult stage is not clear.

Developmental Stages.

Unfortunately, owing to a mixed infection in the breeding pots, it is not possible to ascribe with certainty to one species or the other the two types of larvae obtained. In general form both resemble the species already described, and also in the arrangement of the setae on the head, thorax and abdominal segments I–VIII.

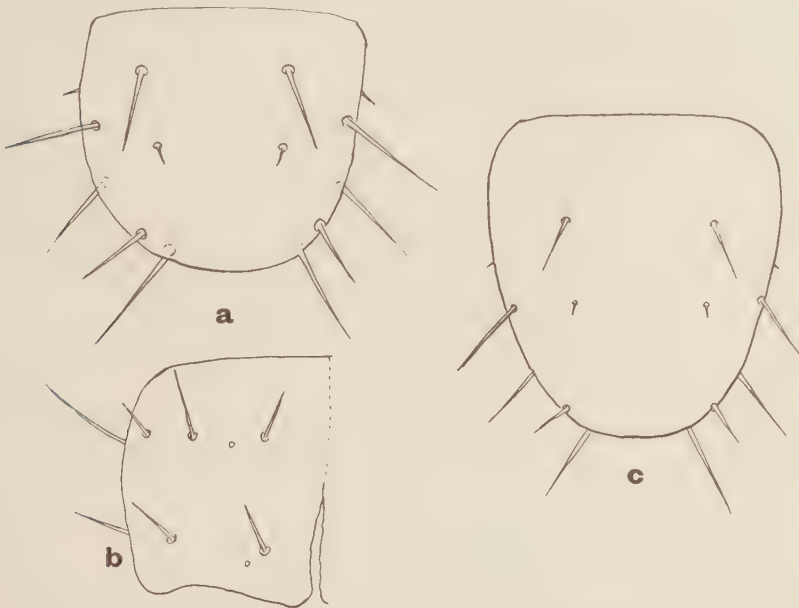


Fig. 11. *a, b*, anal plate and prothoracic shield of *L. succineus*, Foudr. : *c*, anal plate of *L. gracilis*, Kuts.

The prothoracic shield and anal plate of the newly hatched larvae probably referable to *L. succineus* is shown in fig. 11, *a, b*; the more elongate anal plate of *L. gracilis* in fig. 11, *c*.

The pupae are also similar to those of *L. jacobaeae*.

6. Effect on Ragwort.

No experiments have been made with regard to estimating the controlling influence exerted by the beetles on the spread of their host-plant. General observation, however, indicates that this effect is very small. This is largely due to the fact that the time of appearance of the new generations of the three most abundant species does not coincide with that of the germination of the seed and early stages of the seedlings. At this time the beetles are in the larval stage. These larvae will be for the most part on well established second-year plants (for *S. jacobaea* is not an annual) and although very numerous do not noticeably affect the flowering and seeding of the plant; nor does the above-ground feeding habits of the adult beetles seriously affect the plants.

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NOTES ON SOME DIPTEROUS PARASITES OF *SCHISTOCERCA* AND *LOCUSTA* IN THE SUDAN.

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Introduction.

In December 1923 H. H. King bred one male *Sarcophaga* from a living *Schistocerca gregaria* obtained from Kassala, and in August 1927 H. W. Bedford bred one male and two females from *Schistocerca gregaria* from Khartoum. These were described and named *Sarcophaga destructor* by Malloch (1929). In 1930 a consignment of *Sarcophagid* flies bred from melons, tomatos, etc., were examined by Rohdendorf (1930) and identified as *S. destructor*, coupled with the following observation :—

"The 28 ♂♂ and ♀♀ enumerated above from Cyprus and the Sudan make it possible to doubt the correctness of the biological observations of King and Bedford who reared four flies of this species from *Schistocerca gregaria*." Further work on the habits of this insect was indicated. Two lines were taken. The first consisted of rearing *S. destructor* from melons and endeavouring to persuade them to attack locusts, and the second was extensive rearing of flies from parasitised locusts from the Red Sea Coast in an endeavour to recover it from locusts again.

Normal Habits and Early Stages of *Sarcophaga destructor*, Malloch.

Adults of the species are easy to keep in captivity, feeding readily on a variety of substances. Honey, melon juice, sugar solution and locust blood are all attractive to them. The duration of the female adult life is 14–21 days, that of the male being

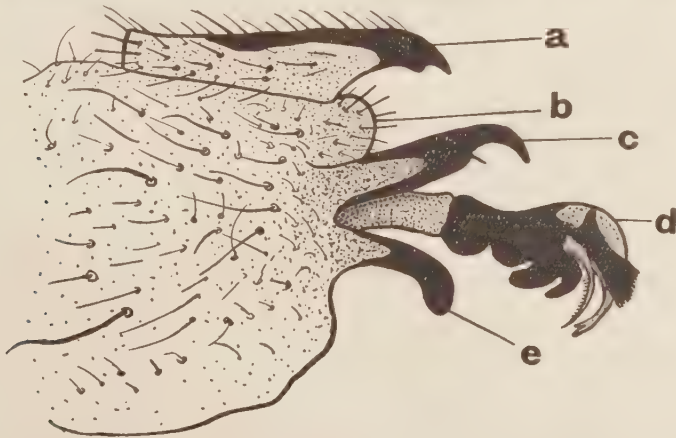


Fig. 1. *Sarcophaga destructor*, Mall., genitalia of ♂: *a*, superior forceps; *b*, inferior forceps; *c*, interior forceps; *d*, paraphallus; *e*, palpus genitalium.

considerably less. Copulation takes place as soon as the flies are dry and continues intermittently for several days. For the first ten days the females are sluggish, but after that the first larvae hatch in the brood pouch and the females commence to search actively for material on which to deposit them. If this is forthcoming, they will immediately deposit 3–6 larvae and repeat this at intervals till the full complement, which varies from 38 to 50, is finished. Ripe and over-ripe fruits are preferred. Considerable damage is done during the winter season by these to the melon, tomatos, and egg-plant crops in the Sudan.

First stage larva (fig. 2).—Newly deposited larvae 1.1 mm. in length by 0.11 mm. in width. Twelve segments with bands of stout bristles at the segmental boundaries. Two posterior spiracles open into a well defined breathing cavity. Each spiracle consists of two stigmal openings from which short tubes lead to the atrium. Colour of atrium and tubes dark brown. Cephalopharyngeal skeleton 0.39 mm. length. Mandibular sclerite strong, with bent fore end. Hypostomal sclerite fused with pharyngeal. Sub-hypostomal sclerite triangular. Oral opening surrounded by a ring of strong bristles. Heavily bristled sub-oval pad. The first stage takes from 29 to 36 hours.

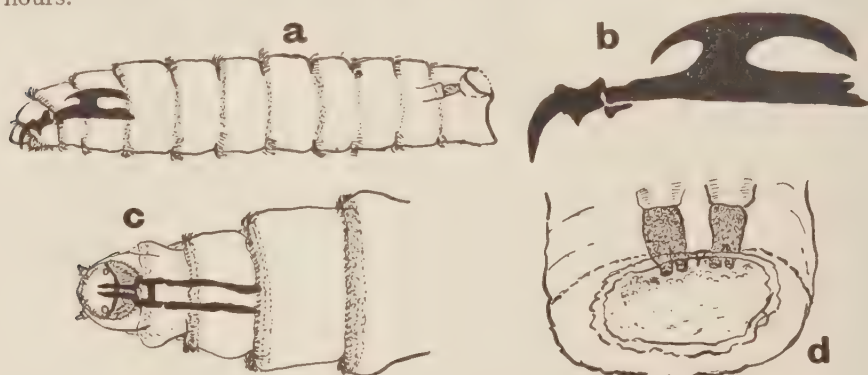


Fig. 2. *Sarcophaga destructor*, Mall.: a, 1st stage larva about 2 mm. in length; b, cephalopharyngeal skeleton; c, same from below; d, posterior spiracles.

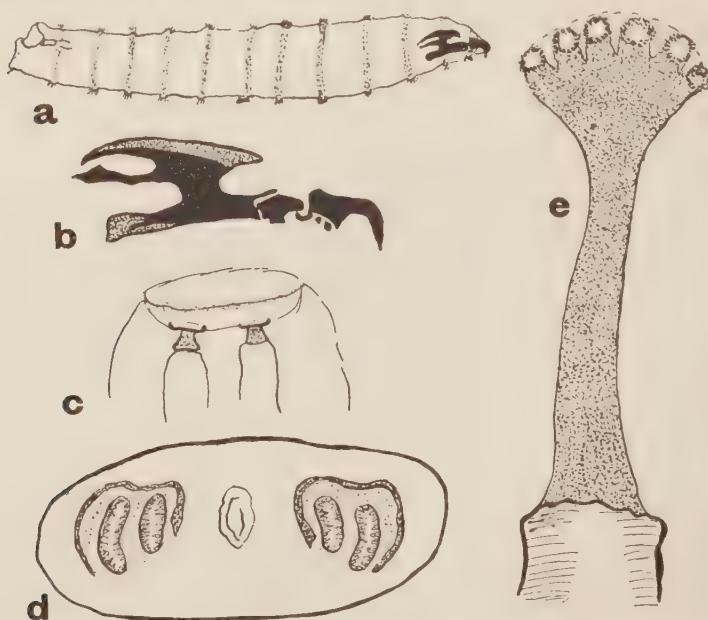


Fig. 3. *Sarcophaga destructor*, Mall.: a, 2nd stage larva; b, cephalopharyngeal skeleton; c, posterior spiracles; d, stigmal plate; e, anterior spiracle.

Second stage larva (fig. 3).—Length 3.5 mm. at the beginning of the stage, diameter 0.5 mm. Bands of spines as in the previous stage. Cephalopharyngeal skeleton 0.53 mm. in length. Mandibular sclerite hammer-head-shaped, separate from

pharyngeal. Sub-hypostomal small, curved. Anterior spiracles with six rays opening into the broad head of the atrium, which narrows into a thin tube about twice as long as the width of the head. Posterior spiracles with paired stigmal plates, each carrying two stigmal openings, the inner one shorter and thicker than the outer. Stigmal edges yellow and dentate. Atrium short, dark brown. Length of second stage 24–36 hours.

Third stage larva (fig. 4).—Length at the beginning 6·7–7 mm. by 1·3–1·5 mm.; when full-grown 9–10 mm. by 1·7–2 mm. Cephalopharyngeal skeleton 1·3 mm. in length. Mandibular sclerite broader, with slightly curved end. The two dental sclerites much more prominent. Hypostomal sclerite irregular in shape. Pharyngeal sclerite with the subdorsal growth heavily pigmented and triangular at the end. Anterior spiracles with six rays opening into a brown pigmented atrium, which is nearly as broad as long. Posterior spiracles, with two plates with three stigmal openings, pale yellow in colour, edges dentate. Atrium short, dark brown. Duration of the third stage 48–72 hours.

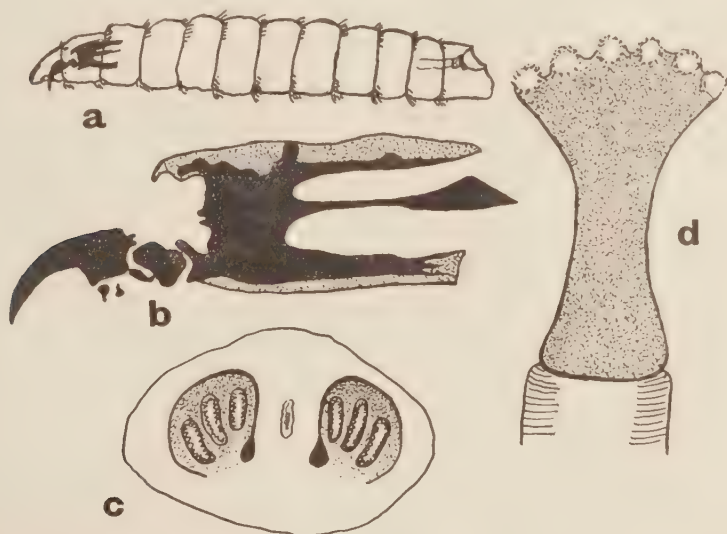


Fig. 4. *Sarcophaga destructor*, Mall.: a, full-grown 3rd stage larva; b, cephalopharyngeal skeleton; c, posterior spiracular plate; d, anterior spiracle.

Pupa.—Dark brown to dark reddish brown. Length 6–7 mm., diameter 2·3 mm. Thickest at the anterior end, tapering slightly towards the posterior end. Deep oral breathing cavity at posterior end with thin irregular walls. Segments clearly defined, with 4–6 bands of small pimple-like bristles. Anterior spiracles orangey red, six-rayed. Duration of pupal stage 12–22 days. Under dry conditions a pupal diapause is sometimes present lasting two to three months. Under moist conditions, in the laboratory, flies emerged at normal intervals all the year round. Flies are abundant in the field from August to February, but in the dry season (February to July) they are exceedingly scarce. Presumably they are carried over the dry season in the resting pupal stage.

***Sarcophaga destructor* and Locusts.**

Experiments of placing flies in cages with locusts in all stages of development were all negative. This, however, could not be accepted as a complete negative, as

most parasitic flies are notoriously difficult to breed in captivity. Baranov's technique (1924-25) was then used to breed them artificially. Moulting locusts had one, two, or three freshly hatched larvae placed on the thorax near the bases of the wings. They immediately pierced the skin with their mouth-parts and disappeared inside the locust. It was found that the time during which the larva was able to penetrate the integument was very short; by the time that the wings had dried the chitin was too hard for the majority of the larvae to penetrate. Only in one case did a larva succeed in penetrating a locust two days after moulting, and that was at the base of one of the posterior wings. For two or three days after larvae had penetrated, the locusts behaved normally, after that they sickened rapidly and died. Three or four days later the fully fed larvae emerged. Of those locusts which had two or more larvae inserted 92 per cent. died, of those with one larvae 16 per cent. only died. On opening the healthy ones the larvae were found to have made slight growth and then died. A further lot of locusts were prepared and at the same time as a control a number of freshly killed locusts were infested with larvae. A number were opened daily from each batch: in the living locusts it was found that the larvae attacked the alary muscles, and, while the locusts were living, made very little increase in size, while those on the dead locusts had grown at the normal rate. In the living locusts the muscular tissue, where the larvae had been feeding, had turned a dirty brown colour, and the pharynx and stomach of the larvae were full of the same dirty brown muscular tissue. By the second and third days the area of infected muscle had spread rapidly and the locust died. The larvae then completed their growth at the normal rate. From this it appears that unless there are sufficient larvae present to cause myiasis and finally the death of the locust, they themselves are unable to live and the locust recovers.

Experiments were made with various substances to try to ascertain under what stimuli the flies would deposit larvae. Moulting locusts had absolutely no attraction for the flies. But it was observed that should any locust be mutilated or bitten by the other locusts the flies immediately went to the wound and after drinking the blood would turn round and deposit three or four larvae in the wound. The same applied to un mutilated locusts, on the thorax of which a drop of fresh locust blood had been placed; larvae were immediately deposited in the blood.

In the winters of 1931-32, 1932-33, large quantities of parasitised locusts were collected from the Red Sea Coast and several hundred flies bred out, but no *S. destructor* were recovered. From the experiments it seems clear that this fly is a feeder on decaying matter. The fact that the larvae can only penetrate the locust for such a short time at the moulting period and the disinclination of the flies to deposit larvae on locusts show that it is not a parasite of locusts. Their readiness to attack slightly mutilated locusts and the fact that the larvae, once they are able to penetrate the locust, are able to cause the death of the locust by myiasis and complete their development, show that an occasional attack on locusts is feasible. There are other similar records in the literature, notably in the case of *S. tuberosa*, the larval habits of which range from saprophagous to parasitic (Aldrich, 1916).

Parasites of Locusts in the Red Sea Coast Area.

Although *S. destructor* was not recovered from the large numbers of flies bred from living locusts, two other species of parasites have been bred: *Blaesoxipha lineata*, Fall., and *Blaesoxipha filipjevi*, Rohd.

The narrow strip of coast between the Red Sea and the Red Sea Hills in the neighbourhood of Port Sudan is exceedingly interesting from the locust point of view. The high humidity, winter rains and flood waterings from khors coming down in spate, mark it off climatically from the rest of the Northern Sudan and afford more

favourable conditions for locusts than the rest of the Northern area. The solitary phases of *Locusta* and *Schistocerca* both occur here in numbers and regular breeding takes place during the winter rains. It is the only place in the Sudan where the solitary phases of *Locusta* have been observed to breed up to the phase *congregans*. In a favourable year several generations are passed through between November and March (Johnston & Maxwell-Darling, 1930).

The regular locust population is also reinforced in the swarming cycle by swarms from other parts of the Sudan. Although the solitary phase of *Schistocerca* is present and breeds over a large area in the Northern Sudan, *Blaesoxipha lineata* has not been recorded from any other locality, and *B. filipjevi* from only two others.

During the last few years officials working on locust destruction in this area (Messrs. Cameron and Maxwell-Darling), reported (unpublished) a fairly heavy parasitisation of both species. In the winter of 1931-32 collections of locusts were made in November and December in this area. The method employed was to collect the locusts in the early morning before they became active; some were opened and examined on the spot and the others kept in cages with sand on the floors and the parasites bred out. The number of locusts infested with larvae started off in November at 15 per cent., and rose to a maximum in December and January to 26 per cent., dropping to 1 per cent. at the end of February and beginning of March. No account was taken of the locusts which had been parasitised and recovered. Both species of locusts were present in fairly equal numbers. On 24th December 1932, a further collection was made by Mr. Rutledge from a large band of *Schistocerca*, phase *congregans*, which had bred up locally and were scattered through the dukhn cultivation (*Pennisetum typhoideum*), 90 per cent. of which had recently become adult. Collections were made in the early morning as in the previous instance. The number of adults containing parasites was 20 per cent. (66 per cent. contained 1 larva only, 20 per cent. 2, 2 per cent. 3, 8 per cent. 4, 2 per cent. 5, 2 per cent. 6). Another 19 per cent. showed holes or scars in the neck indicating recovery from parasitism, giving a total of 39 per cent. parasitised. A few hoppers were present which were nearly all parasitised or showed scars on the neck. Adult flies were observed resting on the herbage in the daytime, and when the locusts were settling down for the night, about four to five o'clock in the winter on the Red Sea Coast, flies were observed flying about them. The following number of flies were bred from adult locusts brought to Khartoum. *B. lineata* 56 per cent., *B. filipjevi* 44 per cent. Both species have been recorded from *L. migratoria* in Russia and extensively studied by Olsuf'ev (1929), whose monograph has been frequently consulted in describing the subsequent larval stages; unfortunately it is in Russian.

Early Stages of *Blaesoxipha lineata*, Fall.

This species has not previously been recorded from the Sudan. It was reared from adults and hoppers of *L. migratoria* and *Schistocerca* (phases *gregaria* and *solitaria*), from Tokar (Red Sea Coast) only. In the months November to February it was abundant in the field. *B. lineata* was bred in the laboratory by natural and artificial means (Baranov's technique). Ripe females were placed in cages with *L. migratoria* in the last nymphal and immature adult stages. Flies were observed continually endeavouring to settle on and deposit larvae on adults. The usual reaction of the locust is a violent jump, which dashes the fly against the opposite side of the cage or the roof. In spite of this a few locusts were successfully parasitised. Only a single larva was found in each locust. Baranov's technique was then resorted to, to maintain a stock. Ripe females were opened and the newly hatched larvae inserted singly, by means of a needle, under a flap of chitin raised on the pronotum. The larvae immediately pierced the underlying skin and the chitin was replaced. A control experiment without inserting the larvae showed that it was harmless to the locust.

Copulation takes place a day or two after emergence. The life of the male is short, 5–10 days, that of the female 14–21 days. The eggs in the two brood pouches hatch 10–14 days after emergence. The number of larvae per female ranges from 83 to 111.

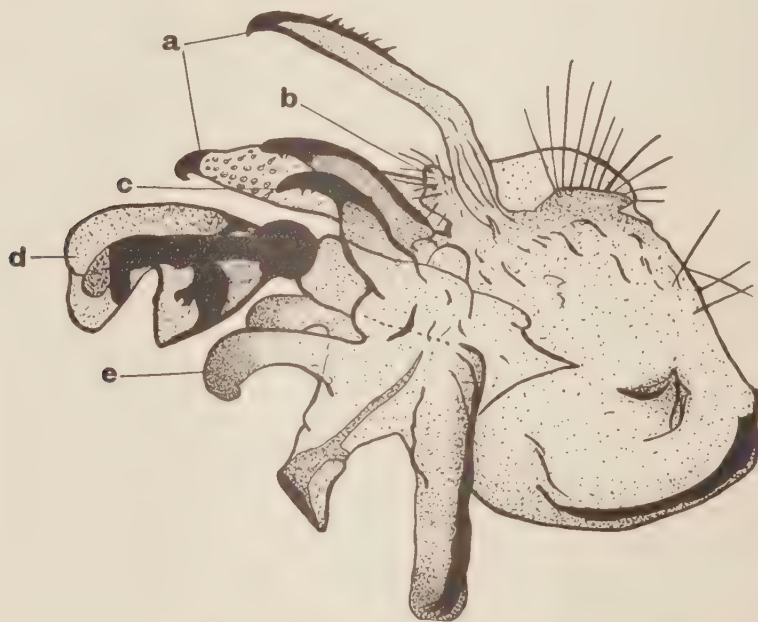


Fig. 5. *Blaesoxipha lineata*, Fall., genitalia of ♂: *a*, superior forceps; *b*, inferior forceps; *c*, interior forceps; *d*, paraphallus; *e*, palpus genitalium.

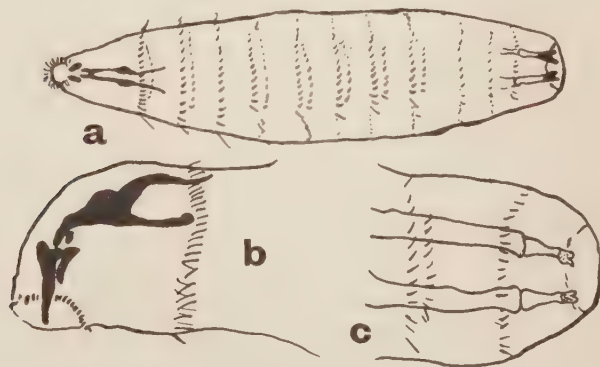


Fig. 6. *Blaesoxipha lineata*, Fall.: *a*, 1st stage larva (ventral view); *b*, cephalopharyngeal skeleton; *c*, posterior spiracles.

First stage larva (fig. 6, *a*).—The newly deposited larva measures 0.77 mm. in length and 0.15 mm. in diameter; head skeleton 0.15 mm. (fig. 6, *b*). Anterior spiracles absent; posterior spiracles with two pairs of stigmata opening into short

orange-red tubes, which open into almost transparent atria. Bristles less than in *Sarcophaga*. On the ventral portion between the sixth and seventh and seventh and eighth segments the bristles consist of a row of fine, followed by a row of thicker, and then another row of fine ones. Duration of first stage 24-48 hours.

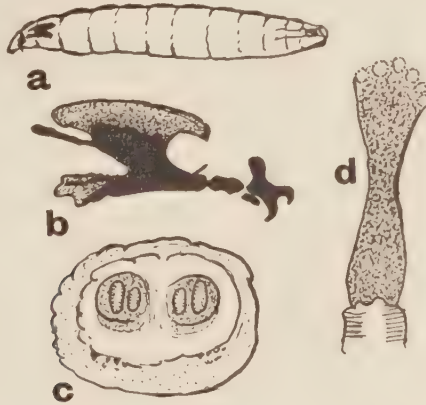


Fig. 7. *Blaesoxipha lineata*, Fall.: a, 2nd stage larva; b, cephalopharyngeal skeleton; c, posterior spiracular plate; d, anterior spiracle.

Second stage larva (fig. 7).—Pale cream-coloured. Length 2.9 mm., diameter 0.4 mm.; head skeleton (fig. 7, b) 0.4 mm. Hypostomal sclerite definitely separated from head. Anterior spiracles pigmented, with 5-7 rays; two pairs of posterior stigmata, pale yellow, the inner one thicker and shorter than the outer, opening into a very lightly pigmented atrium. Bristles present but so transparent that the larva appears naked.

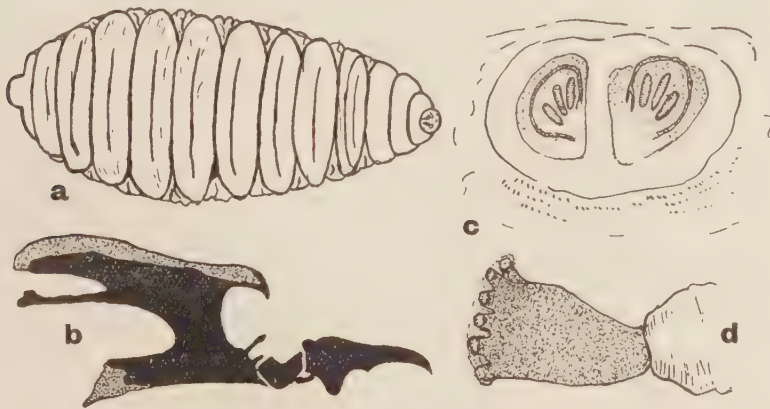


Fig. 8. *Blaesoxipha lineata*, Fall.: a, full-grown 3rd stage larva (ventral view); b, cephalopharyngeal skeleton; c, posterior spiracular plate; d, anterior spiracle.

Third stage larva (fig. 8).—Yellowy cream-coloured, the pharynx and gut often showing bright orange, due to the ingested fat-body of the locust. Shape flat with the last three segments tapering; posterior end rounded; on the ventral surface the skin is thrown into folds. Small transparent bristles present, only seen with careful

magnification. Length at beginning of the stage 5 mm. by 1.5 mm. wide, by 1 mm. deep; when fully grown 9 mm., by 3.5 mm., by 2.3 mm.; mandibular sclerite 0.39 mm. in length. Shallow posterior breathing cavity with smooth rounded edges unlike the thin irregular edges of the cavity of *Sarcophaga* larvae; on its ventral lip there are 3 or 4 rows of small bristles. Anterior spiracles with 5-7 rays. Length of stage 2-4 days.

Pupa.—Average length 5.9-8 mm., diameter 2.4-3.3 mm. Colour variable, from light to dark reddish brown. Anterior end with two stigmata coloured like the rest of the pupa. Segments indefinite; between the segments are two to three rows of bristles corresponding to the larval bristles. Posterior end of the breathing cavity nearly closed in by smooth thick lips (*Blaesoxipha* pupae are easily separated from those of *Sarcophaga* on this point). Length of pupal stage 8-20 days.

Effect of *Blaesoxipha lineata* on Locusts.

After penetrating the locust the larvae make their way to the fat-body in the thorax dorsal to the gut and commence to feed. Daily dissections of locusts, and examination of the stomach and pharynx of all three larval stages, showed that the only part attacked was the fat-body. In a normal locust the quantity of fat-body was more than sufficient for the larva to reach maturity. When two larvae were present all the fat-body was cleared out, but none of the other organs were touched, and in many cases the pharynx and gut of the larvae were nearly empty. If the locust died before the larvae were mature the larvae died also. It was also found that larvae inserted into young hoppers and sexually mature locusts failed to develop and died, while controls inserted into immature adults all matured satisfactorily. The period therefore in which the larvae are able to develop seems to be confined to the last hopper instar and the immature adult stage.

A certain difference of opinion exists as to the effectiveness of this parasite. Baranov (1924) suggests that it might be a possible means of control to release parasitised locusts among unparasitised swarms, while Olsuf'ev (1929) states that it is practically harmless, 85 per cent. recovering. Artificial parasitisation of immature adult *Locusta* in the laboratory showed that though 78 per cent. of the locusts parasitised recovered only 38 per cent. reproduced. In cases where two parasites were inserted the locust invariably died. A small percentage in the field contained more than one larva. From observations and dissections it seemed that the quantity of fat-body present determined the effect on the locust; where the fat-body was short, or two larvae were present, the wanderings of the larvae in search of food damaged the septa and air-sacs, and caused death.

The first generation of flies appears at the end of November and the beginning of December, and two or three generations follow. In February and March they are very scarce, dropping to 1 per cent., and by the end of March they are absent. In the laboratory they bred on till June, when the experiments were discontinued. Probably, as in Russia, they spend the off season aestivating as larvae. Several times in the laboratory a number of larvae were found in the cages that had the appearance of hibernating, but on being disturbed they pupated after a few days.

Blaesoxipha filipjevi, Rohd., and its Early Stages.

This species has not been recorded from the Sudan before. It has a wider range than *B. lineata*. Hosts, recorded in the Sudan, are *Locusta migratoria* and *Schistocerca gregaria*, hoppers and adults, Tokar, November-February; also adult *S. gregaria*, Sinkat, August, and *Anacridium moestum*, adult, Wad Medani (Central Sudan), July. All attempts to breed it naturally in the laboratory failed, but it was bred by artificial means. The life-cycle is similar to that of *B. lineata*.

This species can be easily separated from *B. lineata* on the structure of the male genitalia (figs. 5, 9), the shape of the paraphallus and the inferior forceps being markedly different. In *B. lineata* the superior forceps have spines only on the distal quarter, while in *B. filipjevi* the spines are present only on the basal three-quarters.



Fig. 9. *Blaesoxipha filipjevi*, Rohd.: genitalia of ♂; a, superior forceps; b, inferior forceps; c, paraphallus; d, interior forceps; e, palpus genitalium.

The length of life of the male is 7–16 days, of the female 16–22 days. Larvae are present in the brood pouch 10–16 days after copulation.

First stage larva.—This is similar to that of *B. lineata* with the exception that on the ventral surface between the sixth and seventh and the seventh and eighth segments there is one row of stout bristles followed by two rows of fine ones. Duration 24–36 hours.

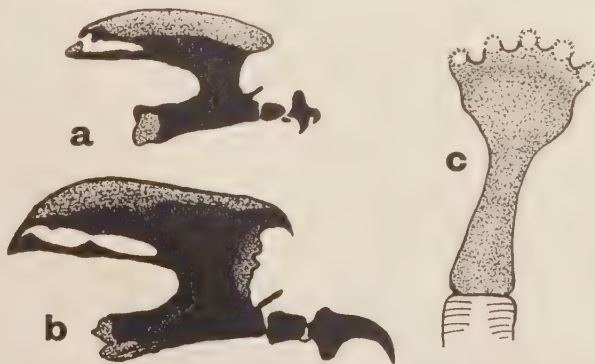


Fig. 10. *Blaesoxipha filipjevi*, Rohd.: a, cephalopharyngeal skeleton of 2nd stage larva; b, cephalopharyngeal skeleton of 3rd stage larva; c, anterior spiracle of 2nd stage larva.

Second stage larva.—Length 3 mm. by 0.4 mm.; cephalopharyngeal skeleton same as *B. lineata* (fig. 10, a), length 0.4 mm. Anterior spiracles (fig. 10, c) differ from those of *B. lineata* in that the head of the atrium is slightly wider, rays 5–7. Duration 48–72 hours

Third stage larva.—Very similar to that of *B. lineata*. Length 5·8 by 1·2 mm. broad, and 0·9 mm. high. Cephalopharyngeal skeleton slightly different. Mandibular sclerite shorter than in *B. lineata*, 0·32 mm. when full-grown (fig. 10, *b*). Length of cephalopharyngeal skeleton 1·1 mm., when full-grown (fig. 10, *b*). Duration 2–4 days.

Pupa.—5 mm. by 1·60 mm. to 7 mm. by 2·2 mm.; slightly shorter but otherwise not different from that of *B. lineata*. Duration 14–17 days.

Effect of *Blaesoxipha filipjevi* on Locusts.

This species feeds firstly on the fat-body, which is enough for one larva. If this is finished before the larvae are full-grown they attack the muscles and other tissues. More are often present in a given locust than *B. lineata*, up to eleven having been bred from one locust. The death of the locust in the early third stage does not have the same adverse effect on the larva as in the case of *B. lineata*. The larvae continue to feed and pupate successfully. The tendency to deposit more larvae and the less specialised feeding of the larvae make it a more efficient parasite than *B. lineata*.

Summary.

(1) The life-history of *S. destructor* was investigated, and it is shown that it is primarily a saprophagous feeder but with distinct potentialities for occasional parasitism.

(2) Two species of parasites were bred out of *Locusta* and *Schistocerca* from the Red Sea Coast: *Blaesoxipha lineata*, Fall., and *B. filipjevi*, Rohd.

(3) The percentage of parasitism was high; 39 per cent. of the adults examined in the area in December 1932 either contained parasites, or had been parasitised and recovered.

(4) The recovery from parasitism was high; 19 per cent. of the locusts examined had been parasitised and recovered.

(5) The life-history of *B. lineata* and *B. filipjevi* was investigated in the laboratory; Olsuf'ev's observation that *B. lineata* is not a very effective parasite was confirmed. A 78 per cent. recovery from parasitism by *B. lineata* was obtained. Only 38 per cent. of the locusts parasitised reproduced.

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RESULTS OBTAINED WITH POLYCHLORIDES AND PARADICHLORO-
BENZENE AGAINST THE LARVAE OF *POLYPHYLLA FULLO*, L., AND
MELOLONTA HIPPOCASTANI, F.*

By Z. S. GOLOVYANKO.

XVI

(PLATE XIV.)

The following is a summary of some experiments that were carried out in 1930, 1931 and 1932 on the sandy soils of Darnitza Forest Reserve (near Kiev) and Krulov Forest Reserve (near Kremenchug), 112 plots, each covering an area of 100 square sazhen (70ft. by 70ft), having been used for the tests. The polychlorides were of two kinds: dark polychlorides, which had a less homogeneous structure and contained a smaller quantity of dichlorides, the amount of higher polychlorides being greater; and light-coloured polychlorides, which chiefly contained dichlorobenzenes and only relatively small quantities of chlorobenzene and higher polychlorides. In the experiments during 1931 and 1932 certain quantities of the chemical were applied to a given area, namely: 26,047 gm., 19,935 gm. and 13,026 gm. to an experimental plot of the size mentioned above. The chemicals were introduced into the soil at intervals of 28, 21 or 14 inches, the lines of the holes being also 28, 21 or 14 inches apart respectively.

The doses applied were as follows:—

Total amount of chemicals in grams per experimental plot	Injection distribution in inches	Doses of paradichlorobenzene and polychlorides in grams
26,047	28 × 28	27.1
26,047	21 × 21	15.5
26,047	14 × 14	7.0
19,535	28 × 28	20.3
19,535	21 × 21	11.6
19,535	14 × 14	5.25
13,026	28 × 28	13.6
13,026	21 × 21	7.75
13,026	14 × 14	3.5

It is, however, necessary to mention that while applying doses of 7.0, 5.25 and 3.5 grams with an injection distribution of 14 by 14 inches, it would be more correct, when testing an injection distribution of 28 by 28 inches, to apply corresponding doses of 28, 21 and 14 grams, instead of 27.1, 20.3 and 13.6 grams as given in the

* Sözialist. Lesnoe Khozyaistvo i Agroleso-Melioratsiya, Kiev, 1933, Nos. 2-3.

table. The doses for an injection distribution of 28 by 28 inches were purposely decreased, taking into consideration that owing to the difficulty of holding the spoon in a horizontal position, the operator introduces into the soil less than the nominal quantity and that the amount of the chemical left over per square unit is usually greater when 28 grams of polychlorides are applied in four separate lots with spoons of 7 gm. capacity, than when the same 28 grams are placed in one hole only with one large spoon.

Two ways of introducing paradichlorobenzene into the soil were tested: distributing it evenly at the bottom of the holes, each measuring 16 square inches, or placing it in a heap in one spot in the hole. Both chemicals were placed in the soil at depths of 4 and 8 inches. Besides 112 treated plots, 19 control plots were used. Two examinations of the control plots showed that in the untreated soil there was a natural decrease in the number of the grubs as a result of normal factors regulating their multiplication.

This natural decrease amounted to 25–50 per cent. during the summer, but had no great influence on the mortality rate (per cent.) resulting from the treatment and therefore need not be taken into consideration when calculating this mortality. The results of treatments in 1930, 1931 and 1932 were as follows (see Tables I–III):—

1. The results of the experiments of 1930 showed the possibility of getting a very high rate of mortality of *Melolontha* grubs (100 per cent. and nearly 100 per cent.) when polychlorides or paradichlorobenzene were applied in plots situated in open areas, as well as under the canopy of a pine forest of medium density.

2. Owing to superfluous moisture in the soil the treatment in 1932 was marked by a decreased effectiveness in comparison with the treatment in 1931; moreover, this decrease in effectiveness was apparent only when large dosages were used at distances of 28 by 28 inches. Differences in the effectiveness of the treatments with the same chemicals and methods were observed not only when comparing the results obtained in different years and at different times in the same treatment period, but also in plots treated simultaneously. In the last case the discordant results are doubtless to be explained by differences in the nature of the soil itself.

3. With the same quantity of the chemical to a given area and the same method of application, paradichlorobenzene is more effective than polychlorides; moreover, this difference is most clearly manifested in those seasons in which the treatment shows decreased effectiveness due to excessive rainfall and lower soil temperature.

4. The light-coloured polychlorides are more toxic than the dark and are not much inferior to paradichlorobenzene, especially in the most effective methods of treatment. It is, however, indispensable to keep in view the fact that under favourable conditions of evaporation and diffusion of the fumes in the soil, the dark polychlorides can also give a very high rate of mortality of the grubs. Thus, for instance, in 1931 these polychlorides applied at the rate of about 1 oz. to each hole at a depth of 4 inches and at intervals of 28 inches (the lines of the holes being also 28 inches apart) gave a kill of 99.3 per cent. of the grubs in a plot in which the infestation before the treatment amounted to 22.5 *Polyphylla* larvae to each square metre. At present a plantation of pines, 80 per cent. of which are in very good condition, is growing on this plot, whereas in an adjoining untreated area all the seedlings were destroyed by the grubs by the end of the summer (see Plate xiv).

5. In the case of both the polychlorides and paradichlorobenzene, the effectiveness was invariably increased if the chemical was placed at a depth of 8, and not 4 inches. This increase did not exceed 8 per cent. when a maximum amount of

the chemical was used to a square unit of the surface ; with smaller quantities of the chemical, however, the increase in the rate of mortality, as result of the introduction of the poison at a depth of 8 inches (instead of 4) reached 12-18, and in some cases even 28-33, per cent.

As the introduction of doses at a depth of 8 inches gives a better result than at a depth of 4 inches, and as in the period of treatment the overwhelming majority of the grubs of *Polyphylla fullo* occur at a higher layer of the soil than the depth of 8 inches, the statement by Jarvis (in Queensland) that it is necessary to introduce paradichlorobenzene into the soil 1 inch above the level of the activity of the grubs, is in no way acceptable under our conditions.

6. Using large doses, which is indispensable if the holes are far apart, paradichlorobenzene placed in a heap gives worse results than when it is loosely scattered and evenly distributed over the bottom of the hole. The reason for this is that the introduction in a heap creates unfavourable conditions of evaporation for large dosages. The use of small dosages renders the difference in effectiveness between the two methods of application insignificant.

The same amount of paradichlorobenzene or polychlorides gave better results when applied in small dosages with a close distribution of the injections (14 by 14 inches), than when large dosages and a sparse distribution (28 by 28 inches) were used.

The less toxic the chemical and the smaller the amount of it used to a given area, the greater is the difference in the effectiveness of the two methods, namely close or sparse injections. We may see from the above the complete lack of foundation for the statement which has appeared in the Russian literature to the effect that polychlorides give a better result when applied in large doses sparsely distributed. What has been said above concerning the higher effectiveness of comparatively small doses placed closer together does not mean, however, that a high rate of mortality cannot be obtained by the use of large doses placed farther apart (28 by 28 inches).

The results of the experiments of 1931-1932 show that in order to obtain not only the maximum effectiveness but also the maximum suitability from an economic point of view, a treatment with dosages of 20-28 gm. and a sparse distribution of the holes (28 by 28 inches), which amounts to 420-550 klgm. to 1 hectare, should be recommended for wide application in our southern sands, provided that the doses are introduced at a depth of 8 inches.

In connection with what has been said about the difference in the effectiveness of light-coloured and dark polychlorides, it is evident that it is advisable to use the light sorts. It would also be possible to use paradichlorobenzene in holes 28 by 28 inches apart with dosages of 21-28 grams, provided that these are evenly distributed over the bottom of the holes ; but as the scattering of the chemical makes the process of treatment slow, in practice it will probably be found more satisfactory to use the same total amount of paradichlorobenzene but distributed at closer intervals ; that is to say, by using smaller doses which can be placed in the holes in heaps without impairing the effectiveness of the treatment.*

When planting trees in a treated area where there has been a heavy infestation of the soil by larvae of *Polyphylla fullo*, dense planting is necessary in order to obtain as soon as possible a canopy that will prevent a fresh mass infestation of the soil by eggs of this beetle.

* Z. S. Golovyanko. Results of the application of paradichlorobenzene against the larvae of the forest cockchafer, *Melolontha hippocastani*, Fabr. Leningrad. 1931. (See Rev. Appl. Ent., A, xx, 1932, p. 145.)

TABLE I.

Results of Soil Treatment with Polychlorides and Paradichlorobenzene in Plots under the Canopy of a Pine Wood in the Darnitza Forest Reserve in 1930.

Number of plot	Chemicals	Injection distribution in inches	Doses in grams	Depths at which chemical was placed in inches	Mortality of <i>Meloloniha</i> %	
					Eggs	Larvae
II	Polychlorides ...	28 × 28	7	4	88.0	64.3
III	Polychlorides ...	14 × 14	7	4	100.0	100.0
IV	Polychlorides ...	14 × 14	14	4	100.0	100.0
V	Polychlorides ...	28 × 28	14	4	96.3	75.7
VI	Paradichlorobenzene	14 × 14	7	4	100.0	100.0

TABLE II.

Results of Soil Treatment with Polychlorides in the Kruilov Forest Reserve in 1931-1932.

Amount of chemical in grams to 600 square yards	Injection distribution in inches	Doses in grams	Depth at which chemical was placed in inches	Type of polychlorides	Mortality of <i>Polyphylla</i> larvae (%)				
					1931		1932		
					I series	II series	I series	II series	III series
13,023	28 × 28	13.6	4	dark	84.3	68.0	54.6	49.9	55.7
				light	—	—	56.7	60.4	67.9
			8	dark	—	—	67.2	77.9	68.0
				light	—	—	80.1	65.9	85.4
	21 × 21	7.75	4	dark	91.1	89.5	—	—	—
	14 × 14	3.5	4	dark	75.0	95.6	90.4	83.8	—
				light	—	—	—	—	81.4
19,535	28 × 28	20.3	4	dark	94.1	75.0	78.4	69.8	58.0
				light	—	—	88.6	78.1	87.3
			8	dark	—	—	88.7	82.1	91.6
				light	—	—	97.2	95.4	100.0
	21 × 21	11.6	4	dark	95.6	93.1	—	—	—
	14 × 14	5.25	4	dark	95.7	86.4	95.7	88.4	—
				light	—	—	—	—	91.5
26,047	28 × 28	27.1	4	dark	99.3	95.1	79.5	85.3	97.3
				light	—	—	89.3	84.8	95.8
			8	dark	—	—	87.4	92.8	97.5
				light	—	—	96.9	92.8	99.5
	21 × 21	15.5	4	dark	96.3	95.9	—	—	—
	14 × 14	7.0	4	dark	98.4	98.7	99.6	98.8	—
				light	—	—	—	—	96.3

EXPLANATION OF PLATE XIV.

Kruilov Forest, near Kremenchug, Central Ukraine.

- Fig. 1. A felled area in which, owing to an extremely severe infestation of the soil by larvae of *Polyphyla fullo*, cultivation of trees was never successful. The area was treated with polychlorides in the spring of 1931, and pines were planted in the spring of 1932. The photograph was taken in the autumn of 1932 and shows that the young plants are in quite a satisfactory condition over the whole area with the exception of its central part which was left untreated and where all the seedlings were destroyed towards the end of their first summer, exactly as had been the case in preceding years.
- Fig. 2. In the middle distance is seen a plot that had been treated with polychlorides in 1931 and planted with pines in 1932 (rows of seedlings in good condition are clearly visible). In the foreground is the untreated plot, on which all the seedlings, planted in the same year (1932), have been destroyed.



Fig. 1.



Fig. 2.

SOME AFRICAN SANDFLIES.

By OSKAR THEODOR, Ph.D.,

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(PLATES XV & XVI.)

This paper deals with a number of collections of African sandflies sent for identification by the Imperial Institute of Entomology and by Dr. P. A. Buxton of the London School of Hygiene and Tropical Medicine. I have to thank Prof. S. Adler for putting some of this material at my disposal.

Since the introduction of the armature of the buccal cavity and pharynx as systematic characters, many new species have been described and a number of doubtful species have been put in their right places. It appears now, however, that some of the characters mentioned above show variations in material of the same species from different localities. It is sometimes difficult to decide whether some of these forms are only local races of the same species or different species. It might become necessary later on to consider some of these forms as independent species, especially if their biology, their feeding habits and therefore their possible rôle in the transmission of disease, show differences which accompany sometimes very small morphological distinctions.

At present, when a great number of differences in the buccal cavity and pharynx have been described, it appears necessary to determine what kind of differences would justify the creation of a new species, and what is the range of variation in a given species which occurs in different localities.

Adler & Theodor (1931) described a number of races of *Phlebotomus chinensis*, which differed in the shape of the penis. In the present paper several varieties of *P. minutus* and *P. africanus* from different localities are described. Some of these varieties show rather marked differences and would perhaps a short while ago have been considered as species, while others would have been called local races. I think it, however, advisable to describe these forms simply as varieties, thus accentuating their near relationship, and to leave it to the future, when our knowledge of them is more complete, to decide whether they are to remain as varieties, or to be considered as local races, or to be raised to specific rank.

***Phlebotomus minutus*, Rond.**

P. minutus is a species very widely distributed round the Mediterranean, in Africa and in Asia. I have examined material from Palestine, Mesopotamia, India, Turkestan, Algeria, the Sudan and the Gold Coast. Among this material 5 (or 6) different forms with more or less pronounced characters could be distinguished. In nearly all these forms the main difference was in the armature of the buccal cavity and in some cases also in the pharynx. These differences were constant in all the specimens from one locality.

P. minutus was first described with modern methods by Newstead from Malta in 1911. Adler & Theodor in 1926 described the buccal cavity of *P. minutus* from Palestine, and Sinton upon examining a cotype of Newstead's from Malta found its buccal cavity identical with that of the species described by Adler & Theodor from Palestine. Adler & Theodor failed to find *P. minutus* in Malta and Southern Italy during four years' search, where they found only a variety of *P. parroti*. In the light of Sinton's re-examination of the specimens caught by Newstead in Malta, it is most likely, but not certain, that the form from Algeria would be identical

with that caught in Malta and should therefore be considered as the typical form of the species and all the other forms as varieties. (The sandfly fauna of Algeria and that of Southern Italy and Malta is rather similar.) Since I have had no opportunity of comparing the different varieties at my disposal with Newstead's specimens and the main purpose of this paper is to point out the differences between the various forms without definitely deciding their specific rank, I shall leave the question unsettled for the moment.

***P. minutus* from Palestine, Mesopotamia and India.**

The armature of the buccal cavity and the pharynx of *P. minutus* from Palestine has been described by Adler & Theodor (1926 & 1927). It consists of a row of ca. 24 pointed teeth standing on an arc strongly concave posteriorly. The lateral teeth are constantly larger than the middle ones (fig. 1, *a*). In some of the other forms this difference between the lateral and the median teeth is much less marked and this may partly be due to individual variation; e.g., some specimens from Baghdad

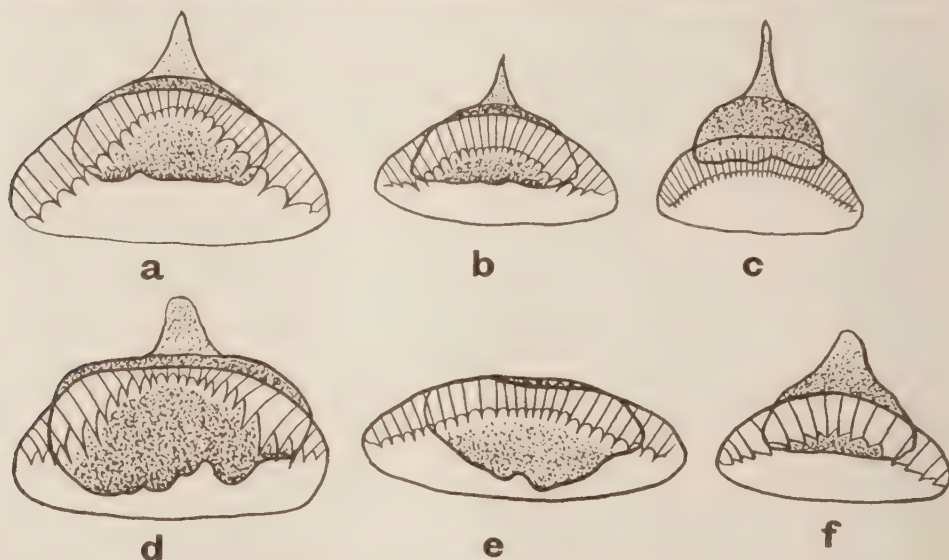


Fig. 1. Armature and pigmented area of the buccal cavity of the female of: (a) *P. minutus* from Palestine; (b) *P. minutus* var. *signatipennis*; (c) *P. minutus* var. *occidentalis*; (d) *P. minutus* var. ? *antennatus* from Africa; (e) *P. minutus* var. ? *antennatus* from India; (f) *P. minutus* var. *arpaklensis*.

show a marked difference between the lateral and median teeth, while in other specimens all the teeth are of nearly equal size. Probably this is simply due to a more or less marked curvature of the plate of the buccal cavity on which the teeth stand, which presses the middle teeth more closely together. The apparent length of the points of the teeth depends on the angle at which the buccal cavity remains after death, and this angle is also variable. If the teeth lie horizontally, they appear longer and pointed; if they stand more vertically, they appear shorter and blunter. The pigmented area in the Palestinian form is roughly oval, sometimes roughly triangular with the apex pointing anteriorly. In the Mesopotamian form it is always triangular. Palp formula: 1, 2, 4, 3, 5. The fourth segment is always very slightly shorter than the third. Antennae: segment $3 < 4 + 5$, its length 0.083 to 0.11 mm. in the female, 0.095 to 0.13 mm. in the male. The Palestinian form is nearly always rather dark, the pigmented area nearly black. The Mesopotamian form is generally smaller than the Palestinian one, of much lighter colour, and the pigmented area dark brown rather than black.

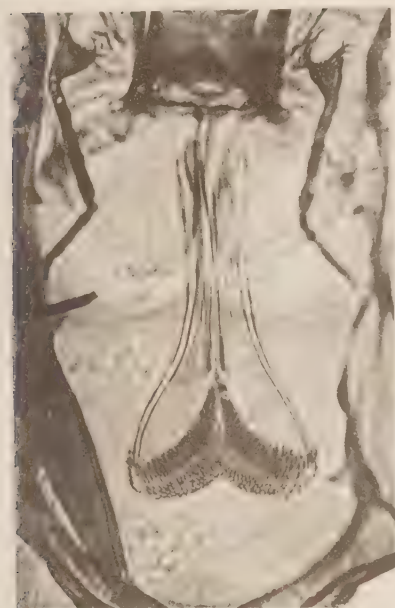


Fig.1 *P. minutus* from Palestine

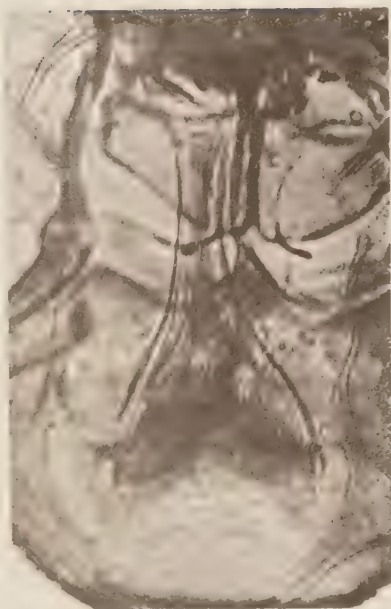


Fig.2. *P. minutus* var. ?*antennatus*
from Africa.



Fig.3. *P. minutus* var. ?*antennatus*.
from India.

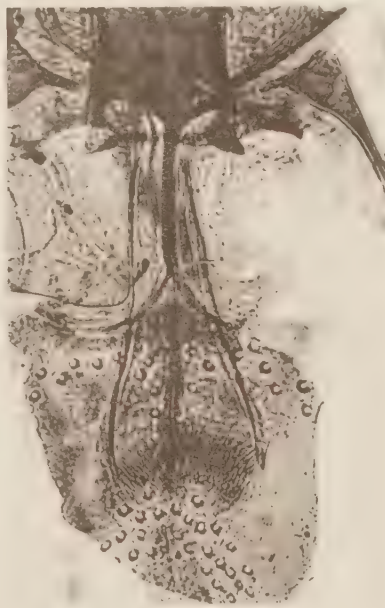


Fig.4. *P. minutus* var. *arpaklensis*.

PHARYNX OF FEMALE *PHLEBOTOMUS* (x about 350).

Two females and one male from India kindly sent by Lt.-Col. Sinton show all the characters described above for *P. minutus* from Palestine.

***P. minutus* var. *signatipennis*, Newstead (North African form).**

The armature in the buccal cavity differs from that of the Palestinian and Mesopotamian form in the greater length and width of the median teeth. The difference between the lateral and median teeth is therefore much less marked. The pigmented area is always roughly triangular (fig. 1, *b*). Pharynx as in the Palestinian form. Antennae: length of the third segment 0.08 to 0.13 mm. Palps as in the Palestinian form.

This form has been found in Algeria and the Sudan.

Material examined: 10♀♀, Aroma, Kassala, Sudan, 27.ii.26 (*H. H. King*); 10♀♀, 1♂, Wad Medani, Sudan, 30.iv.23 (*H. B. Johnston*).

***P. minutus* var. *occidentalis*, nov. (West African form).**

The armature in the buccal cavity consists of a row of 24 to 27 very narrow, nearly equal teeth standing on an arc not so strongly concave posteriorly as in the other forms described above. Pigmented area roughly triangular with long apex anteriorly, very dark (fig. 1, *c*). Antennae: length of third segment 0.08 to 0.09 mm. in the female, 0.1 mm. in the male. In other respects it resembles the other forms.

Material examined: 25♂♂, 57♀♀, Tamale, Gold Coast, 1932 (*Selwyn Clarke*); 4♂♂, 19♀♀, Gadau, Northern Provinces, Nigeria, Sept.-Oct. 1929.

***P. minutus* var. ? *antennatus*, Newstead.**

The species *P. antennatus* was described by Newstead from the Gold Coast on the strength of the very short third antennal segment. Later Newstead & Sinton (1921) compared it with *P. minutus* and called it *P. minutus* var. *antennatus*. Sinton found a form of *P. minutus* in India with a similarly short third antennal segment, which he considered to be identical with Newstead's *P. minutus* var. *antennatus*. In a later paper (1932a) he figured the buccal cavity and the pharynx of this form.

In a collection of sandflies from the Gold Coast I found two specimens which differ markedly from all the other specimens from the same locality described above as *P. minutus* var. *occidentalis* and show similar characters to those figured by Sinton for the Indian form, *i.e.*, a broader armature in the buccal cavity and a much broader pharynx with far more numerous and smaller teeth than in the other forms. The lateral teeth in the buccal cavity are much larger than the middle ones (fig. 1, *d*). The third antennal segment is however not shorter than in the other forms ("less than 90 μ " (Sinton)) but this character shows individual variation. Most of the other varieties show in some individuals an even shorter third antennal segment. The pigmented area is roughly elliptical with a ragged posterior border.

A comparison of the two specimens from the Gold Coast with some specimens of *P. minutus* var. *antennatus* which Lt.-Col. Sinton kindly sent me showed that the pharynx in the Indian and West African forms is very similar, except that the deep indentation of the posterior border in the Indian specimens is absent in the African ones and that the teeth in the pharynx are finer and more numerous in the Indian form (Plate XV, figs. 2, 3). Further, the difference between the lateral and median teeth in the buccal cavity of the African form is much slighter in the Indian form (fig. 1, *e*). The palp formula in the Indian specimen is: 1, 2, 3, 4, 5; relative length of segments: 1, 2.2, 3.5, 3.9, 8.5. This palp formula is different from that of all other varieties of *P. minutus*. The West African form has the typical *minutus* palp formula 1, 2, 4, 3, 5; relative length of segments: 1, 2.1, 3.3, 3, 5. The third antennal segment in the Indian specimens is not relatively

shorter than in many other specimens of other varieties described above, e.g., of *P. minutus* var. *occidentalis*. This character is thus too variable for purposes of classification.

It appears therefore that the Indian and African forms are not identical. What *P. minutus* var. *antennatus* really is cannot be decided without an examination of Newstead's specimens. Probably Newstead dealt with the variety described as *occidentalis* in the present paper. If this should be found to be the case the Indian form will have to be made an independent variety.

P. minutus var. ? *antennatus* from the Gold Coast is most nearly related to the Palestinian form of *P. minutus*, from which it is distinguished mainly by its broader pharynx with its more numerous teeth. The form described by Parrot as *P. minutus* var. *antennatus* from the Congo clearly does not belong to this variety but more likely to one of the two varieties *signatipennis* or *occidentalis*. This cannot yet be decided as the armature in the buccal cavity has not been figured.

Material examined: 2 ♀♀, Tamale, Gold Coast, 1932 (*Schweyn Clarke*); 1 ♀, Gadau, Northern Provinces, Nigeria, Sept.-Oct. 1929.

***P. minutus* var. *arpaklensis*, Perfiliev (1933).**

A very small dark species.

♀. Size: 1.45 to 1.6 mm. Wings: Length 1.4 mm., breadth 0.27 mm., index $\alpha/\beta = 0.35$ to 0.75. Palp formula: 1, 2, 4, 3, 5; relative length of segments: 1, 2.1, 3.6, 3.4, 6. Antennae: segment $3 < 4 + 5$ and shorter than epipharynx.

$$\frac{A \text{ III}}{E} = 0.6 \text{ to } 0.7.$$

Buccal cavity with the armature consisting of 10 to 16 broad teeth with short points which stand on an arc strongly concave posteriorly; the pigmented area is triangular (fig. 1, f). Pharynx much narrower than in *P. minutus*, only 2.25 to 2.5 times as wide posteriorly as anteriorly with relatively few, rather coarse teeth (Plate XV, fig. 4). Spermathecae tubular as in *P. minutus*.

♂. Size: 1.45 mm. Wings: length 1.4 mm., breadth 0.23 mm., index $\alpha/\beta = 0.25$. Palps as in ♀. Antennae: segment $3 < 4 + 5$ and longer than epipharynx.

$$\frac{A \text{ III}}{E} = 1.27.$$

Buccal cavity similar to that of ♀, containing about 10 broad pointed teeth; pigmented area small, triangular. Pharynx slender, with an armature of rows of very small point-like teeth and a number of larger pointed teeth. Genitalia like those of *P. minutus*, except that the small ventral seta on the apical segment of the superior clasper is situated at the level of the two sub-apical spines and not, as in *P. minutus*, at the apical quarter of the segment.

This variety is very clearly distinguished from *P. minutus* by the number and shape of the teeth in the buccal cavity and by its much narrower pharynx. The male is distinguished from *P. minutus* by the greater length of the third antennal segment, which in *P. minutus* is shorter or rarely as long as the epipharynx, and by the position of the ventral seta on the apical segment of the superior clasper.

Material examined: 2 ♀♀, 1 ♂, Termes; 7 ♀♀, 1 ♂, Tashkent, 1928; 1 ♀, Merv, 1930; 1 ♀, Kara Kala, 1930 (*Perfiliev*).

***Phlebotomus africanus*, Newstead.**

This species was described by Newstead (1912) from East and West Africa as a variety of *P. minutus*. Adler & Theodor (1926) found that the buccal cavity, pharynx and spermathecae differed from those of *P. minutus* and raised it to specific rank.

P. africanus is widely distributed in Equatorial Africa. It has not been found in North Africa or in the Western Mediterranean, where *P. parroti* is prevalent instead. Three different forms have to be distinguished. The form distributed in the Sudan and Congo is undoubtedly to be considered as typical. There is another form found in Palestine and in India and still another one found so far only in one locality in the Sudan.

P. africanus has 35 to 40 parallel teeth in the buccal cavity standing on a straight line or on an arc very slightly concave posteriorly. There is a row of very small point-like teeth at the base of the main row, each of these small teeth being situated at the base of about every third tooth (fig. 2, *b*). There are several rows of rather small, pointed teeth in the posterior narrow part of the pharynx (fig. 2, *e*).

Material examined: 11 ♀♀, Agur Koalib, Sudan, 24.vi.1925 (*W. Rutledge*); 5 ♀♀, Gadau, Northern Provinces, Nigeria, Sept.-Oct. 1929.

***P. africanus* var. *asiaticus*, nov.**

The teeth in the buccal cavity are more numerous as a rule (44 to 50) and the row of small point-like teeth is absent (fig. 2, *a*). The teeth in the posterior narrow part of the pharynx are long and pointed and fewer than in *P. africanus* from the Congo (fig. 2, *d*).

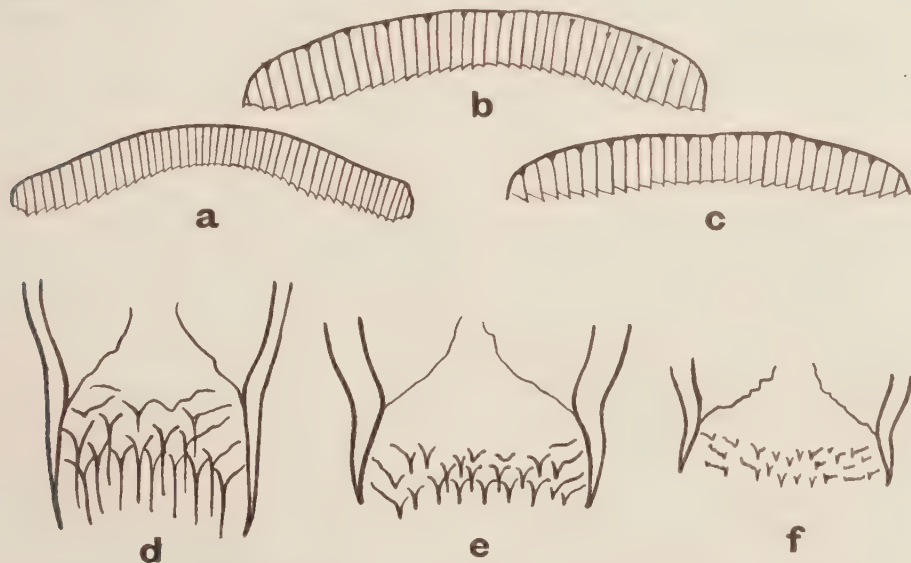


Fig. 2. Armature of the buccal cavity of the female of: (a) *P. africanus* var. *asiaticus*; (b) *P. africanus*; (c) *P. africanus* var. *sudanicus*. Posterior narrow part of the pharynx of the female of: (d) *P. africanus* var. *asiaticus*; (e) *P. africanus*; (f) *P. africanus* var. *sudanicus*.

Distribution: Palestine. I have had no opportunity of examining specimens from India.

***P. africanus* var. *sudanicus*, nov.**

The teeth in the buccal cavity are only 30 to 33 in number and there is a small point-like tooth at the base of every second tooth of the armature (fig. 2, *c*). The teeth in the narrow posterior part of the pharynx are much smaller than those in *P. africanus*, sometimes appearing as rows of points (fig. 2, *f*).

Material examined : 4 ♀♀, 5 ♂♂, Aroma, Kassala, Sudan, 27.ii.1926 (H. H. King).

There are several other forms allied to *P. africanus* whose position is not quite clear. *P. africanus* var. *magnus*, Sinton, described from South Africa, is probably only a large specimen of *P. africanus*. Sinton's *P. freetownensis*, which differs from *P. africanus* mainly in the greater number of teeth in the buccal cavity, might also be considered a variety of *P. africanus*, since the above descriptions show that the number of the teeth in the buccal cavity is variable. The same applies to *P. barraudi*, Sinton.

***Phlebotomus congolensis*, Beq. & Walr., 1930.**

My attention has been called by Dr. L. Parrot to a paper by Bequaert & Walravens in which the authors describe *P. africanus* var. *congolensis* and *P. katangensis*. A short time ago Dr. Bequaert sent me some specimens of his *P. africanus* var. *congolensis*. They are clearly identical with *P. nairobiensis* described by the writer in 1931. This sandfly is quite distinct from *P. africanus* and has therefore to be made a species with the name of *P. congolensis*.

***P. congolensis* var. *distinctus*, nov.**

Size, palps and wings as in *P. congolensis*.

Buccal cavity with the armature consisting of ca. 24 teeth standing on an arc moderately concave posteriorly. The armature is similar to that of *P. minutus*, i.e., the 6 lateral teeth are rather large with long points and the middle teeth are much shorter and narrower (fig. 3, a). In *P. congolensis* there are 34 to 40 teeth, the

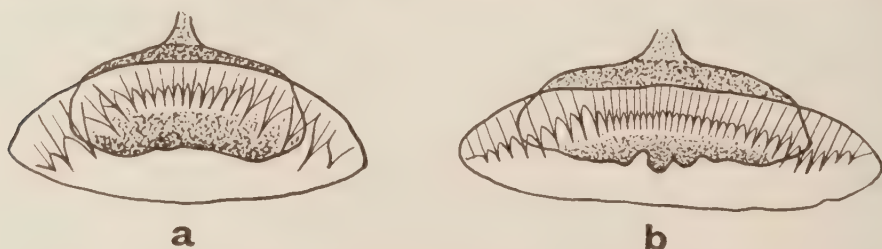


Fig. 3. Armature and pigmented area of the buccal cavity of the female of (a) *P. congolensis* var. *distinctus*; (b) *P. congolensis*.

difference between the lateral and median ones being much less marked; the arc on which they stand is rather flat (fig. 3, b). The pigmented area in *P. congolensis* var. *distinctus* is similar to that of *P. congolensis*, but its posterior border is generally smooth, not ragged as in *P. congolensis*. Pharynx similar to that of *P. congolensis*, but the band of teeth in the posterior widened portion is broader and more strongly curved anteriorly and the individual teeth are larger. Posteriorly the pharynx is more strongly bulged than in *P. congolensis* (Plate XVI, figs. 1, 2).

There is only one detail of external morphology distinguishing var. *distinctus* from *P. congolensis*. The third antennal segment in the male is constantly shorter than the epipharynx, while in *P. congolensis* it is as long or longer. The males of *P. congolensis* and var. *distinctus* are otherwise nearly indistinguishable. The teeth in the buccal cavity of var. *distinctus* are generally fewer and the lateral teeth larger than in *P. congolensis*, but their number and size are rather variable. There are no differences between the male genitalia of the two forms.

Material examined : 18 ♀♀, 14 ♂♂, Tamale, Gold Coast, 1932 (Selwyn Clarke); 3 ♀♀, 2 ♂♂, Mongalla Prov., Sudan, 1922 (Dr. Rosie); 2 ♀♀, Agur Koalib, Sudan, 25.vi.26 (W. Rutledge).

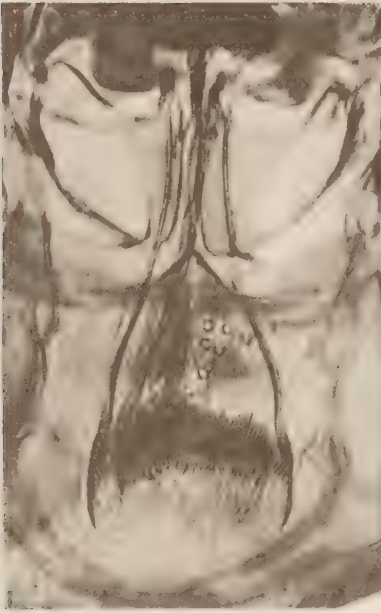


Fig.1 *P. congolensis* Pharynx of ♀

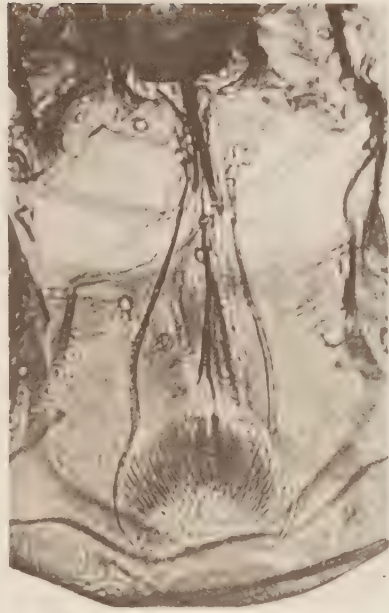


Fig.2. *P. congolensis* var. *distinctus*
Pharynx of ♀.

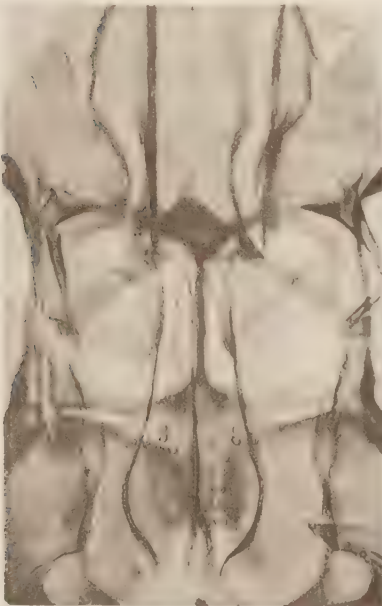


Fig.3. *P. adleri*. Pharynx and buccal
cavity of ♀.



Fig.4. *P. affinis*. Pharynx and buccal
cavity of ♀.

PHARYNX AND BUCCAL CAVITY OF *PHLEBOTOMUS* (x about 350).

***Phlebotomus katangensis*, Beq. & Walr., 1930.**

I have examined one male of this species which Dr. Bequaert kindly sent me. It clearly belongs to the *major* group, but its male genitalia are quite different from those of all other species of this group. This is the first record of a species of the *major* group from Equatorial Africa, the occurrence of which in that area was assumed by Adler & Theodor (1931) in the discussion on the possible carrier of Kala-azar in the Sudan. (The description of *P. katangensis* was not known to us then.)

***Phlebotomus adleri*, sp. n.**

♀. Size: 1.9 to 2.45 mm. Wings: length 1.75 to 1.9 mm., breadth 0.36 to 0.4 mm., index $\alpha/\beta=0.45$ to 0.73. Palp formula: 1, 2, 4, 3, 5; relative length of segments: 1, 1.8, 3.4, 2.4, 4.7. Antennae: segment $3 < 4+5$, and considerably shorter than the epipharynx. $\frac{AIII}{E}=0.65$.

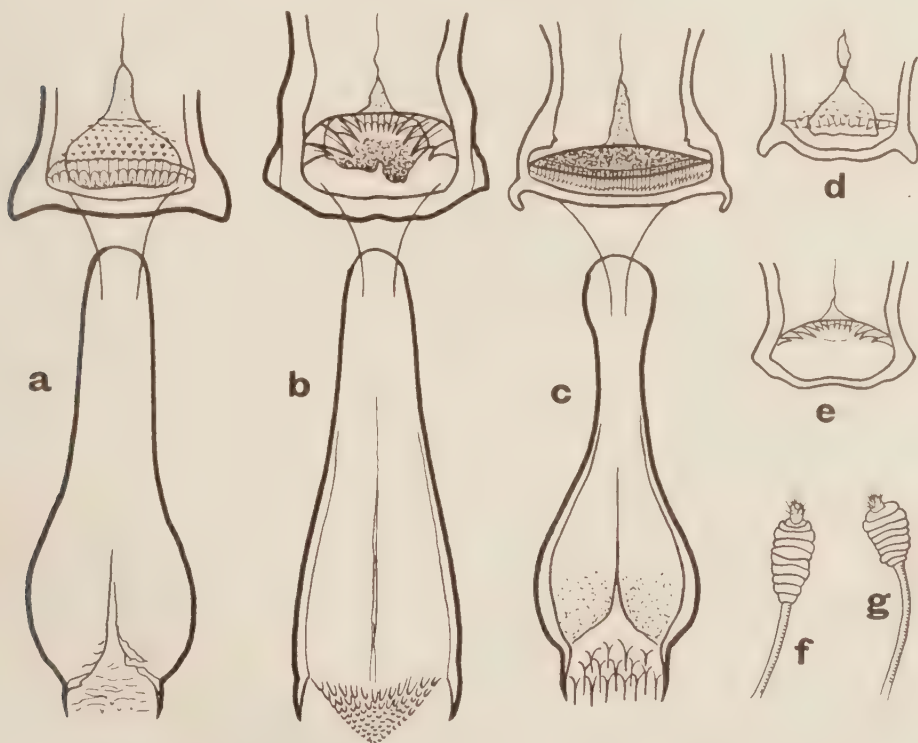


Fig. 4. Buccal cavity and pharynx of female of: (a) *P. adleri*, sp. n.; (b) *P. buxtoni*, sp. n.; (c) *P. affinis*, sp. n. Buccal cavity of male of: (d) *P. adleri*, sp. n.; (e) *P. buxtoni*, sp. n. Spermatheca of: (f) *P. adleri*, sp. n.; (g) *P. affinis*, sp. n.

Buccal cavity with the armature consisting of a straight row of ca. 20 long pointed teeth, anteriorly to which there are 4 to 5 rows of small point-like teeth; the pigmented area is large, roughly heart-shaped with a blunt apex anteriorly (text-fig. 4, a and Plate XVI, fig. 3). Pharynx lamp-glass-shaped with a few minute teeth posteriorly; 2.5 times as broad posteriorly as anteriorly. Spermathecae with 10 to 12 segments, similar to that of *P. tiberiadis*, *P. hospitii*, etc., and with very long, narrow ducts with separate openings (fig. 4, f).

♂. Size : 2 mm. Wings : length 1.75 mm., breadth 0.35 mm., index $\alpha/\beta=0.33$ to 0.6. Palps as in ♀. Antennae : segment $3 < 4 + 5$. $\frac{A III}{E}=0.75$ to 0.86.

Buccal cavity similar to that of the ♀, with one row of 10 to 12 teeth standing on a straight line, but in some specimens each of these teeth bears 2 to 3 small secondary teeth at its apex ; anteriorly to the main row there are 2 to 3 rows of small point-like teeth ; the pigmented area is faint, triangular, with the apex anterior (fig. 4, d). Pharynx similar to that of the ♀, very slightly chitinated, twice as broad posteriorly as anteriorly, with some very faint ridges in the posterior part. Genitalia : second segment of the superior clasper half the length of the first segment or slightly less ; two apical and two subapical spines, the small ventral seta slightly below the middle of the segment ; middle clasper moderately hooked, unarmed ; penis pointed, tapering, slightly bent upwards ; inferior clasper shorter than the first segment of the superior clasper (fig. 5, a).

P. adleri is easily distinguished from all other species of the *minutus* group in the Old World. The row of teeth in the buccal cavity is similar to that of *P. collarti*, from which it differs in its segmented spermathecae and in the presence of several rows of small teeth in the buccal cavity. This feature has been observed in most of the species from South America that I have examined, and in the Old World in *P. zeylanicus* and in *P. montanus*. From *P. zeylanicus* it is distinguished by the position of the spines on the second segment of the superior clasper of the male, which are typical for the *minutus* group in *P. adleri*, while in *P. zeylanicus* two of them are apical and two situated in the middle of the segment. I do not know of a description of the spermathecae of *P. zeylanicus*, but as Sinton does not include the species in his group with scanty erect hairs on the abdomen, which all have segmented spermathecae, I assume that they are not segmented. There are also differences in the length of the third antennal segment and in the relative lengths of the third and fourth palpal segments. The arrangement of the teeth in the buccal cavity in *P. montanus* is quite different.

I have much pleasure in dedicating this species to Prof. S. Adler.

Material examined : 1 ♀, 1 ♂, Accra, Gold Coast ; 5 ♀♀, 10 ♂♂, Tamale, Gold Coast, 1932 (*Selwyn Clarke*).

***Phlebotomus buxtoni*, sp. n.**

♀. Size : 2.45 mm. Wings : length 1.95 mm., breadth 0.49 mm., [index $\alpha/\beta=0.9$. Palp formula : 1, 2 (3, 4), 5 ; relative length of segments : 1, 2.3, 3.4, 3.5, 4.5.

Antennae : segments $3 < 4 + 5$, and shorter than the epipharynx. $\frac{A III}{E}=0.74$.

Buccal cavity with the armature consisting of a row of 15 to 16 teeth standing on an arc concave posteriorly ; four lateral teeth very large and broad, and their points directed towards the middle line ; the 7 or 8 middle teeth very narrow and pointed and parallel to the long axis of the body ; the pigmented area is irregularly elliptical, its posterior border ragged and its anterior border nearly straight with a short apex anteriorly (fig. 4, b). Pharynx twice as wide posteriorly as anteriorly, with an armature of short stumpy teeth ; in the only specimen found the armature looks triangular with the apex posterior, but this may be accidental, as the pharynx is distorted ; it rather resembles that of *P. schoutedeni* (fig. 4, b). Spermathecae tubular, as in *P. minutus*.

♂. Size, wings and palps as in the ♀. Antennae : segment $3 < 4 + 5$, longer than the epipharynx. $\frac{A III}{E}=1, 2$.

Buccal cavity with about 14 teeth standing on an arc slightly concave posteriorly, the lateral teeth larger than the middle ones, pointing towards the middle line; no definite pigmented area visible (fig. 4, *e*). Pharynx slender, with no distinct armature. Genitalia: two long apical spines, two markedly subapical ones on the distal segment of the superior clasper; the small ventral seta rather near the base of the two subapical ones, in one specimen at the apical quarter of the segment; middle clasper with blunt end; penis blunt, finger-shaped, curved downwards; inferior clasper shorter than the basal segment of the superior clasper (fig. 5, *b*).

The armature in the buccal cavity of *P. buxtoni* resembles somewhat that of *P. decipiens*, from which it is distinguished by the presence of an armature in the pharynx, and by the tubular spermathecae. (Cylindrical capsules in *P. decipiens*.) From *P. schoutedeni*, which it resembles in the pharynx, spermathecae and in several characters of external morphology, it is distinguished by the armature in the buccal cavity, which has about 20 narrow teeth in *P. schoutedeni* without the marked difference between the lateral and median teeth which is so characteristic in *P. buxtoni*.

Material examined: 1 ♀, 1 ♂, Tamale, 1 ♂, Accra, Gold Coast, 1932 (*Selwyn Clarke*).

I have much pleasure in dedicating this species to Dr. P. A. Buxton of the London School of Hygiene and Tropical Medicine.

***Phlebotomus affinis*, sp. n.**

♀. Size 2.2 mm. Wings: length 1.7 mm., breadth 0.43 mm.; index $\alpha/\beta=0.6$. Palp formula: 1, 2, 3, 4, 5; relative length of segments: 1, 2.4, 3, 4, 7.5. Antennae: segment 3 > 4+5, longer than the epipharynx. $\frac{A_{III}}{E}=1, 15$.

Buccal cavity with the armature consisting of a row of 40 equal, narrow, parallel teeth with short points; the whole armature markedly convex posteriorly and closely resembling that of *P. parroti*; the pigmented area is a narrow elongated ellipse, stretching across the whole breadth of the buccal cavity (text-fig. 4, *c*, Plate XVI, fig. 4). Pharynx faintly chitinised, lamp-glass-shaped, in its widest portion behind 3 times as broad as anteriorly; the armature consisting of relatively few, moderately long, thin teeth in the posterior narrow portion (fig. 4, *c*). Spermathecae with about 8 segments and very narrow long ducts; length of capsule 0.09 mm., breadth 0.04 mm. (fig. 4, *g*).

♂ unknown.

P. affinis belongs to Sinton's group with scanty erect hairs on the abdomen, which all possess segmented spermathecae (*P. hospitii*, *christophersi*, *clydei*, *eadithae*, etc.). It is easily distinguished from all these species except *P. hospitii* and *P. eadithae* by the armature in the buccal cavity. In *P. hospitii* the number of teeth in the buccal cavity is 50 to 60 and the pigmented area is mushroom-shaped.

P. affinis is very nearly related to *P. eadithae*, Sinton, from which it can be distinguished by the following characters:—The number of the teeth in the buccal cavity is greater than in *P. eadithae* (35), the third antennal segment is shorter than 4+5 in *P. eadithae* and longer in *P. affinis*. The shape of the pigmented area is different. The third palpal segment in *P. eadithae* is nearly as long as the fourth, while in *P. affinis* it is only three-quarters of the length of the fourth segment. The spermathecae have only 8 segments instead of 12.

Material examined: 1 ♀, Mongalla Prov., Sudan, 1932 (*Dr. Rosie*).

***Phlebotomus* sp.**

♂. Size: 1.55 mm. Wings: length 1.7 mm., breadth 0.4 mm.; index $\alpha/\beta=0.66$. Palp formula: 1, 2, 4, 3, 5; relative length of segments: 1, 1.8, 3.4, 3, 6.3. Antennae lacking.

Buccal cavity with two rows of very small, point-like teeth standing in groups of four to five, with some slightly bigger pointed teeth at the lateral angles; no pigmented area visible (fig. 5, *d*). Pharynx slender, unarmed. Genitalia: distal segment of the superior clasper rather long, longer than half the basal segment; four long, rather thin spines, of which two are apical and two slightly subapical; the small ventral seta stands between the middle and the apical third of the segment, middle clasper hooked; penis slender, tapering, with two processes basally (fig. 5, *c*).

Material examined: 1 ♂, Agur Koalib, Sudan, 26.vi.1925 (*W. Rutledge*).

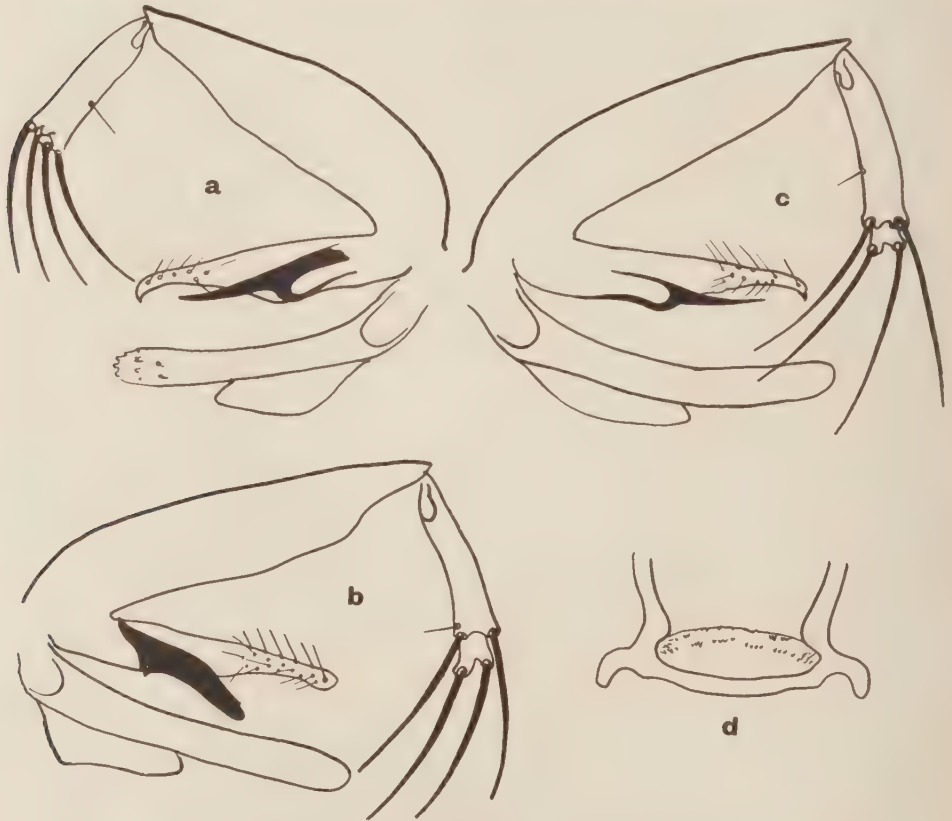


Fig. 5. Male genitalia of: (a) *P. adleri*, sp. n.; (b) *P. buxtoni*, sp. n.; (c) *Phlebotomus*, sp. n.; (d) buccal cavity of male of *Phlebotomus*, sp. n.

The male described above resembles *P. bailyi*, Sinton, in the structure of the armature of the buccal cavity, but its palpal formula is 1, 2, 4, 3, 5, instead of 1, 2, 3, 4, 5 as in *P. bailyi*, and the position of the small ventral seta on the distal segment of the superior clasper is also different. But as the male may belong to a species already described from a female only, I think it advisable not to name it for the present.

***Phlebotomus ingrami*, Newstead.**

In the re-description of *P. ingrami* by Adler, Theodor & Parrot (1929) the antennae of the female were not described, as they were lacking in the only specimen at our disposal. I take this occasion to complete the description.

Antennae: segment $3 \geq 4 + 5$, longer than the epipharynx. $\frac{A\ III}{E} = 1.23$.

In 1929 we stated that there was no pigmented area in the buccal cavity. In the three specimens from Fort Portal there is a pigmented area of brown colour, which is roughly oval or nearly round, its anterior border being flattened.

Material examined : 3 ♀♀, Fort Portal, Uganda, 4.x.31 (E. G. Gibbins).

***Phlebotomus schwetzi*, Adler, Theodor & Parrot.**

Material examined : 4 ♀♀, Tamale, Gold Coast, 1932 (Selwyn Clarke).

***Phlebotomus schoutedeni*, Adler, Theodor & Parrot.**

Material examined : 1 ♀, Fort Portal, Uganda, 4.x.31 (E. G. Gibbins).

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THE SYNONYMY AND DISTRIBUTION OF *CHRYSOMYIA RUFIFACIES* (MACQ.), AN AUSTRALIAN SHEEP BLOWFLY.

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Introduction.

Chrysomyia rufifacies, originally named *Lucilia rufifacies*, was described by Macquart in 1843 from specimens collected in "New Holland." Although Macquart attributed the species to Guérin, there appears to be no record of a description by him.

For many years the species has been known to have a wide distribution in Australia, but it was not until about 1912 that it was included among the species attacking sheep. Froggatt has referred to it as *Calliphora rufifacies*, *Pycnosoma rufifacies* and *Chrysomyia albiceps*. The last determination, made in 1921, was the result of correspondence with Patton, who has variously determined the species as *Chrysomyia albiceps* and *C. albiceps* var. *putoria*. Patton thus considered that the essentially Palaearctic *C. albiceps*, the Ethiopian *C. putoria* and the Australian *C. rufifacies* were identical, or at most varieties of one species. Most authors have followed Patton in determining the Australian species as *Chrysomyia albiceps*. (Mercier (1927) adopted this determination, for, when mentioning the presence of *C. albiceps* in Northern France, he referred to it as the Australian hairy sheep maggot fly.) Malloch (1926, 1927), however, doubted the correctness of Patton's determination and Bezzi (1927) and Miss Aubertin (1932) considered that *Chrysomyia rufifacies* was a valid species.

There is thus considerable diversity of opinion as to the correct status of the three forms *C. albiceps*, *C. rufifacies*, and *C. putoria*. The present study was therefore undertaken as an attempt to clear up the existing confusion.

C. rufifacies and *C. albiceps* compared.

Every effort has been made to locate the type of *C. rufifacies*, but if ever there was one it is apparently no longer in existence. However, through the courtesy of Mr. J. E. Collin, the present holder of the Bigot collection, I have been able to examine specimens which, in the absence of a type, are probably the next best thing. They are labelled "*rufifacies*" in what is known to be Macquart's handwriting. The specimens are in poor condition but served for an examination of those characters of greatest interest in the present study. Through the courtesy of Dr. F. W. Edwards of the British Museum and Dr. Zerny of Vienna, I have been able to examine the type of *C. albiceps* which is lodged in the Vienna Natural History Museum.

Macquart's original description of *C. rufifacies* and Wiedemann's description of *C. albiceps* offer little assistance in the separation of the two species. In the two descriptions the only character which approaches being distinctive is the colour of the antennae; slight differences in venation are also indicated. Both these characters have been examined in a large series of the two species. In *C. rufifacies* the third segment of the antenna ranges from light brown on the anterior (dorsal) edge to darker brown posteriorly (ventral), whereas in *C. albiceps* the third segment is uniformly very dark or blackish brown. The angle at which M_1 (apical section of fourth longitudinal vein) leaves M_{1+2} (fourth longitudinal vein) is almost a right angle in *C. rufifacies*, whilst in *C. albiceps* it is definitely acute. Associated with the acute

angle in *albiceps* there is usually a short spur, the remnant of M_2 , which is generally absent in *rufifacies*. Neither the antennal nor the venational character is sufficiently distinctive for separating the two species.

Bezzi (1927) has used the presence or absence of a strong bristle below the prothoracic spiracle for distinguishing these two species. This bristle (the stigmal bristle) is situated on the anterior ventral portion of the mesopleura. Its position is shown in fig. 1a. It is present in *C. rufifacies* and absent in *C. albiceps*. Patton (1925) has questioned the validity of this character and has stated that the type of *C. albiceps* possesses a bristle in this region. I could find no indication whatever on the type of a bristle in this position. It seems possible that one of the propleural bristles, which are situated just anterior to this region, may have appeared to arise below the spiracle instead of anterior to it.

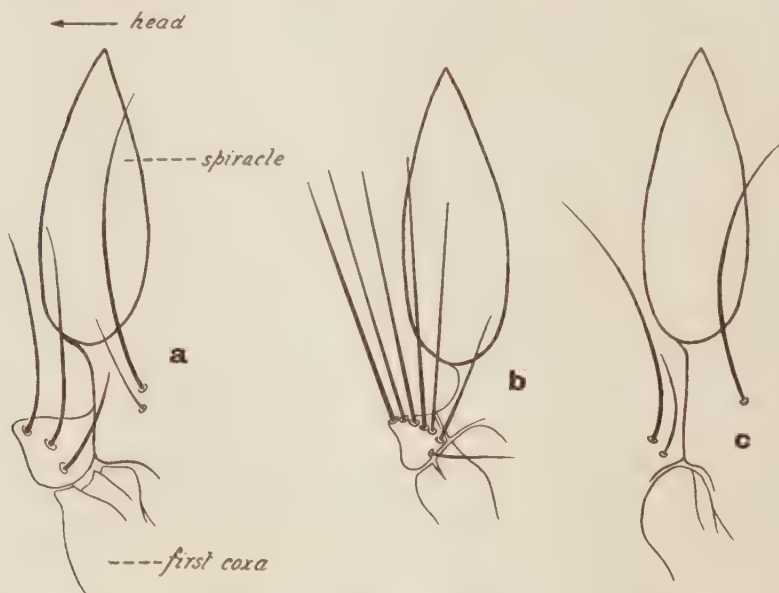


Fig. 1. Setae in the region of the prothoracic spiracle of: (a) *C. rufifacies*, Macq.; (b) *C. albiceps*, Wied.; (c) *C. putoria*, Wied.

Occasionally there is a very small seta on the stigmal area, in *C. albiceps*, but its size never approaches that of the stigmal bristle in *C. rufifacies*. Its occurrence has been noted six times on 114 wings examined.

In general there is no difficulty in distinguishing the two species by the bristle character. Another character which is less easy to see, but which can be used for supporting evidence, is found in the propleural bristles, which are situated anterior to the stigmal bristle and near the first coxa. In *C. albiceps* the normal condition is that there is no stigmal bristle and there are from four to six propleural bristles. In *C. rufifacies* there is one large stigmal bristle, sometimes with a small seta, and 2 to 4, usually 3, propleural bristles.

Chrysomya putoria, Wied., which Patton has also considered to be a synonym of *C. albiceps*, has been examined for these characters. In this species there is a single very stout stigmal seta below the spiracle and the propleural group is represented by a single bristle of similar size. Occasionally the propleural bristle has associated with it a second much smaller seta. The usual condition found in the three species is indicated in fig. 1.

The following key will serve to separate the three species :—

1. No stigmatal bristle present ; occasionally a very small seta in this region ; propleural bristles 4–6 ; abdominal bands narrow..... *albiceps*
A stout stigmatal bristle present, sometimes a small seta also.....2
2. A single propleural bristle sometimes with an additional small one ; abdominal bands approximately equal to one-third of the segment.....*putoria*
Propleural bristles 2–4, usually 3 ; abdominal bands considerably less than one-third of the segment, almost linear.....*rufifacies*

The Genitalia of *C. rufifacies* and *C. albiceps*.

The male genitalia of the two species yield evidence supporting their separation (figs. 2, 3, 4). Séguy has figured the genitalia of *C. albiceps* twice, one figure evidently having been made from a microscopic preparation. However, more detail is required



Fig. 2. *C. rufifacies*, Macq.: genitalia of ♂.

for distinguishing the two species than Séguy has given. The structures exhibiting the greatest differences are the apodeme and genital sternite.* In *C. albiceps*, both structures are stouter, more heavily chitinised and bear transverse chitinisations towards the extremities, whereas in *C. rufifacies* they are narrower, membranous and not transversely banded. In *C. albiceps* the apodeme is laterally compressed and strongly ridged longitudinally, and the end of the genital sternite is shovel-shaped. In *C. rufifacies* the apodeme is ridged, but is not laterally compressed, and the genital sternite is much flatter at its extremity.

* The terminology is that used by Séguy and is in fairly general use for Muscoid flies.



Fig. 3. *C. albiceps*, Wied.: genitalia of ♂.

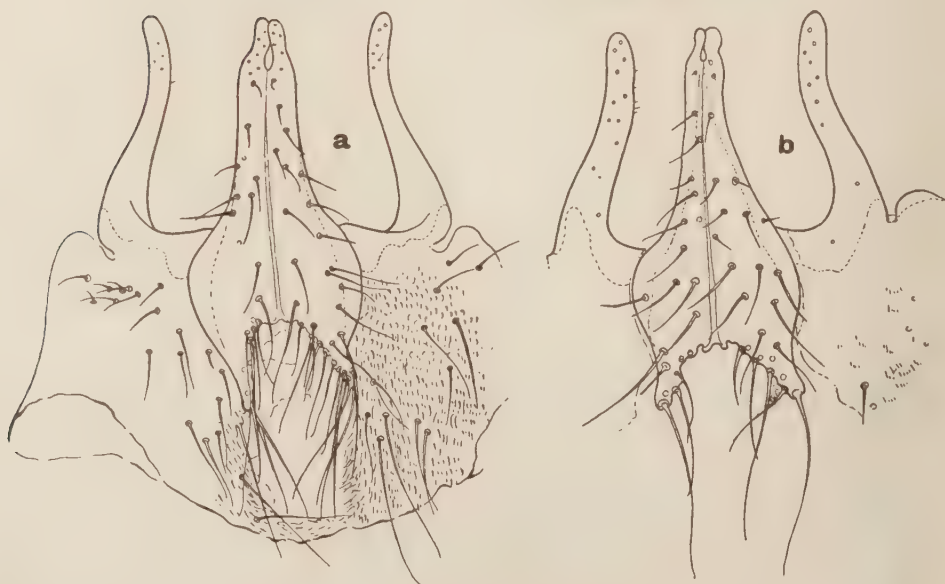


Fig. 4. Forceps of: (a) *C. rufifacies*, Macq.; (b) *C. albiceps*, Wied.

The external forceps (fig. 4) are broader in *rufifacies* than in *albiceps*; the tergite is more densely haired in *rufifacies* than in *albiceps* (figs. 2, 3). The two species appear to differ in the attachment of the penis. In *albiceps* the attachment of this organ to the base of the apodeme is apparently by means of a separate articulating bar (the theca) whereas in *rufifacies* the penis is continuous to the base of the apodeme. This apparent difference in attachment may be due to the relative positions in which the parts remained at death. But against this is the fact that the condition observed in each species was constant in all specimens of each species examined. Also, the condition seen in *albiceps* agrees with that figured by Séguy. The difference observed, if really constant, indicates important structural differences in the genitalia of the two species. Differences in the praeputium figured are also apparently constant.

The Synonymy of *C. rufifacies* (Macq.).

The following is the synonymy of *Chrysomyia rufifacies*, Macq., so far as it has been possible to obtain it from the literature :—

Lucilia rufifacies, Macquart 1843.

Calliphora rufifacies (Macq.) det. Lw., Brauer & Bergenstamm 1891, Jarvis & Cory 1913, Froggatt 1914.

Pycnosoma rufifacies (Macq.), Froggatt 1915, '16, '17.

Chrysomyia albiceps (Wied.), Froggatt 1921, '22, Patton 1921, '22, Johnston 1922, '23, Johnston & Tiegs, 1922, Johnston & Hardy 1923, Senior-White 1926, Gurney & Woodhill 1926, Malloch 1927.

Chrysomyia rufifacies (Macq.), Malloch 1924.

Chrysomyia albiceps var. *putoria* (Wied.), Patton 1925.

Chrysomyia albiceps var. *rufifacies* (Macq.), Patton 1929.

Chrysomyia (*Achaetandrus*) *rufifacies* (Macq.), Bezzi 1927.

<i>Somomyia saffrana</i> , Bigot	} Apud Bezzi 1927.
<i>S. melanifera</i> , Bigot	
<i>Lucilia ispida</i> , Erichson	

? *Lucilia tasmanensis*, Macq.

? *Compsoomyia tasmanensis*, Macq., Séguy 1928.

It is clear from Séguy's work that Macquart's *Lucilia tasmanensis* is a Chrysomyiine. Séguy's description, made from the type, fits *rufifacies* quite well, except that the genitalia are described as being " exactly like the typical form (*albiceps*). " The genitalia of *rufifacies* and *albiceps* are similar in general form and, although differences are there, they may not be evident to a person not looking specially for them.

Further, Hardy (1929) has pointed out that most of the " Tasmanian " material described by Macquart in 1850 in the Fourth Supplement, actually came from the vicinity of Sydney. The only Chrysomyiine fly occurring at Sydney, which at all fits Séguy's description of *tasmanensis* is *C. rufifacies*, to which *Lucilia tasmanensis*, Macq., should no doubt be referred.

The Distribution of *C. rufifacies* (Macq.), *C. albiceps* (Wied.) and *C. putoria* (Wied.).

Examination of a long series of the three species makes it possible to give a fairly good idea of the distribution. The type localities are as follows :—

C. rufifacies, Macq.—Australia (" New Holland ").

C. albiceps, Wied.—Cape of Good Hope.

C. putoria, Wied.—Sierra Leone.

In the following table, unless otherwise indicated, the specimens have been examined by the author. The distribution records are indicated further in the accompanying map.



Fig. 5. The distribution of *Chrysomya rufifacies*, Macq., *C. albiceps*, Wied., and *C. putoria*, Wied.

Chrysomyia rufifacies, Macq.

AUSTRALIA. *Queensland*: Brisbane, Inkerman, Townsville, Cairns, Eidsvold Springsure, Stannary Hills; Winton (M. Fuller); Nicholson River, Normanton (Mackerras); Dunk Island (Hacker); Aramac (Aust. Mus.). *New South Wales*: Hawkesbury River, Rowena, Barrington Tops, Sydney, Tumut, Bargo; Moree (Gurney & Woodhill); Yarrowin, North West N.S.W., and Uralla (Froggatt); Brewarrina, Dorrigo, Narromine (Aust. Mus.). *F.C.T.*: Canberra. *Victoria*: Bright (Bezzi). *South Australia*: Adelaide, Farina and Kangaroo Island (Aust. Mus.). *West Australia*: Waroona, Wyndham; Fitzroy River (Mackerras); Perth, Chapman, Perenjori, Wongan Hls., Beverley, Merredin (Newman). *Northern Territory*: Alexandria, Katherine, Burnside, Newcastle Waters, Mary River, Marrakai, Daly River.

NEW ZEALAND.—Wellington.

PACIFIC OCEAN.—New Caledonia, Samoa, Marquesas Is., Hawaiian Is., Fiji, Tonga (Bezzi).

JAVA.—Buitenzorg (Mackerras).

INDIA.—Madras, Benares, Khasi Hills, Assam (Senior-White).

CEYLON.

Chrysomyia albiceps, Wied.

PALAEARCTIC REGION.—*France*: Toulouse, Arles, Hyères; Calvados (Mercier). *Southern Europe* (Séguy). *Turkey* (Séguy). *Asia Minor* (Séguy). *North Africa*: N.W. Africa (Séguy), Cairo.

SOUTHERN AFRICA.—*Southern Rhodesia*: Bulawayo, Salisbury. *Transvaal*. *Orange Free State*: Dewetsdorp. *Cape Province*: Grootfontein.

INDIAN OCEAN.—Seychelles Island, Rodriguez Island, Madagascar.

Chrysomyia putoria, Wied.

AFRICA.—*Anglo-Egyptian Sudan*. *Sierra Leone*: Freetown. *Nigeria*: Kano, Sherifuri, Azare, Lagos. *Gold Coast*: Ashanti. *Belgian Congo*. *Uganda*. *Portuguese East Africa*: Lorenzo Marques. *Nyasaland*: Blantyre, Lake Nyasa. *Southern Rhodesia*: Bulawayo, Salisbury.

It will be seen from these records and the accompanying map that *C. albiceps* is dominantly Palaearctic, occurring also in South Africa and the adjacent islands of the Indian Ocean; *C. putoria* is dominantly Ethiopian; and *C. rufifacies* is Oriental and Australian. (Senior-White's specimens, considered by him to be *putoria*, are now in the British Museum and have been determined by Miss Aubertin as being *rufifacies*.)

In view of the confusion which formerly existed regarding the identity of the species dealt with in this paper, it is not known to which species the Indian forms determined by Patton as *C. albiceps* belong. The species from Java recorded by Malloch (1926) as *albiceps* is no doubt *rufifacies*.

In Africa *C. albiceps* is replaced in the tropics by *C. putoria*. The limits of distribution of the two species *albiceps* and *putoria* correspond very closely with the 80°F. mean annual isotherm (see Clayton's "World Weather"). This isotherm, running through Southern Rhodesia, passes northward along the coast and across the Indian Ocean in the vicinity of the Seychelles Islands. From this point, still passing north, it crosses the equator and then passes south in the vicinity of Java. In the Northern Hemisphere it passes across Northern Africa just south of the Tropic of Cancer in the region of the Northern Sudan, thence across Central Arabia, the Persian Gulf and Northern India.

The distribution records for *C. rufifacies* suggest that it has a wider temperature range than either *C. albiceps* or *C. putoria*.

The Genus *Chrysomyia*.

The genus *Chrysomyia* (originally spelt *Chrysomya*) was proposed by Robineau-Desvoidy in 1830. He made no mention of a genotype. Rondani in 1863 included *Musca marginalis*, Wied. 1830, and proposed it as type. Townsend (1915) has drawn attention to the fact that *M. marginalis* was not originally included in the genus by Robineau-Desvoidy and thus could not be considered the genotype. In 1907 Bezzi showed that *Chrysomyia regalis*, R. Desv. 1830, a species originally included in the genus, is a synonym of *Musca marginalis*, Wied. 1830. Coquillett (1910) and Townsend (1915) considered that Bezzi's determination validated Rondani's selection of the genotype. *Chrysomyia regalis*, R. Desv. (= *M. marginalis*, Wied.) is therefore the type of *Chrysomyia* and Ségué's subsequent statement (1928) that *C. idioidea* is the type is incorrect.

Brauer & Bergenstamm, in 1894, designated *M. marginalis* as the type of their new genus *Pycnosoma*. *Pycnosoma* is therefore an absolute synonym of *Chrysomyia*. According to Bezzi & Stein (1907) and Coquillett (1910) a further synonym is *Paracompsomyia*, Hough 1898.

Recently Ségué (1928) has split *Chrysomyia* into three genera, *Compsomyia*, *Pycnosoma* and *Somomyia*. I have examined representatives of these groups and on evidence from larvae and adults am inclined to agree with Ségué's action. However, his selection of names for the new restricted genera is not justified.

1. Ségué discards the name *Chrysomyia*, and adopts Brauer & Bergenstamm's name *Pycnosoma* for the group of which *Musca marginalis*, Wied., is the type. As shown above *Pycnosoma* is an absolute synonym of *Chrysomyia* and the latter name should therefore be used for this group.

2. *Somomyia* was proposed by Rondani in 1861. It replaced *Mya*, Rondani 1850, which was preoccupied. No genotype was named for either genus. *Musca segmentaria*, Fabr., an originally included species, was designated the genotype of *Mya*, Rond., by Coquillett (1910). By Art. 30, Sec. f. of the International Code, it therefore also becomes the genotype of *Somomyia*, Rond. Consequently, the name *Somomyia* should be applied to the group of Neotropical species which includes *segmentaria*, Fabr., and not to the Oriental group to which Ségué has applied it. *Hemilucilia*, Brauer 1895, has the same genotype and is an absolute synonym of *Somomyia*, Rond.

3. *Compsomyia* was proposed by Rondani in 1875 and included European and East Indian forms. Brauer & Bergenstamm (1894) selected *C. macellaria*, Fabr. (North American "screw-worm") as the type of *Compsomyia*. Villeneuve (1914) and Townsend (1915) pointed out that *C. macellaria* was not an originally included species of *Compsomyia* and was moreover not congeneric with the other forms. Townsend therefore erected the genus *Cochliomyia* for *C. macellaria* and thus left *Compsomyia* still without a genotype. Coquillett in 1910 selected *Musca dux*, Esch. (= *megacephala*, Fabr.) as type of *Compsomyia*. Ségué's *Somomyia* which included *megacephala* should therefore be *Compsomyia*.*

4. Ségué used the name *Compsomyia* for the group which contains the species with tuberculate larvae. Neither this name nor any other of the older generic names can be applied to this group. The name *Achaetandrus*, Bezzi (type *Chrysomyia albiceps*) is available. Ségué's *Compsomyia* should therefore be *Achaetandrus*, Bezzi 1927. (The spelling given in Bezzi's paper in which the sub-genus *Achaetandrus* was erected is "*Achoetandrus*." The character from which the name is derived is the

* Bezzi & Stein (1907) treated *Somomyia* as a synonym of *Calliphora* because Rondani had included *C. erythrocephala* in *Somomyia*. In view of the evidence given above this action appears to have been incorrect.

absence of frontal bristles in the male. It is therefore concluded that there is an error in spelling, possibly due to the fact that Bezzi's papers were usually submitted for publication in script. The spelling has therefore been corrected to "*Achaetandrus*."

The fate of the names used by Séguy would thus be :—

Pycnosoma would become *Chrysomyia*.
Somomyia " " *Compsomyia*.
Compsomyia " " *Achaetandrus*.

The synonymy of these genera and *Cochliomyia* is as follows :—

Chrysomyia, R.-D. 1830 (Genotype : *Chrysomyia regalis*, R.-D. = *M. marginalis*, Wied., by designation of Rondani 1864).

Synonyms : *Pycnosoma*, Br. & Berg. 1894, Séguy 1928 ; *Paracompsomyia*, Hough, apud Bezzi & Stein 1907, Coquillett 1910.

Somomyia, Rond. 1861 (Genotype : *Musca segmentaria*, Fabr., by subsequent designation of Coquillett 1910).

Synonyms : *Mya*, Rond. 1850, praeocc. ; *Hemilucilia*, Brauer 1895 ; *Calliphora*, Bezzi & Stein 1907 in part, nec R.-D. 1830.

Compsomyia, Rond. 1875 (Genotype *Musca dux*, Esch. = *megacephala*, Fabr., by subsequent designation of Coquillett 1910).

Synonyms : *Chrysomyia* in part, auctt. nec R.-D. ; *Somomyia*, Séguy, nec Rond.

Achaetandrus, Bezzi 1927 (Genotype *Chrysomyia albiceps*, Wied., by original designation of Bezzi 1927).

Synonyms : *Chrysomyia* in part, auctt. nec R.-D. 1830 ; *Compsomyia*, Séguy 1928, nec Rond. 1875 ; *Pycnosoma* in part, auctt. nec Br. & Berg. 1894 ; *Somomyia*, Rond. 1873, in part (Section including genotype).

Cochliomyia, Towns. 1915 (Genotype *Cochliomyia macellaria*, Fabr., by original designation of Townsend).

Synonyms : *Compsomyia*, Br. & Berg. 1894, nec Rond. 1875 ; *Chrysomyia*, auctt., nec R.-D. 1830.

For the present I have retained the name *Chrysomyia* for the *Achaetandrus* group. Nevertheless the time is ripe for a complete revision of all the genera of the CHRYSOMYIINI and it seems to me probable that eventually this group will have to be separated off as a distinct genus. The position is as follows : In the CHRYSOMYIINI there are a number of groups of species of which those discussed here can be distinguished on the following characters.

(a) The *marginalis* group.—Flies dominantly metallic blue to violet or green with prominent black bands on the posterior margin of the abdominal segments. Both males and females with a prominent row of frontal bristles but no outer vertical setae in the males. Females with more than one pair of fronto-orbitals—two or three pairs.

External forceps of the genitalia with branches short, broadly triangular in outline with rounded extremities. Internal forceps, branches very short, scarcely twice as long as broad, with rounded extremities. Penis elongate, lateral branches of paraphallus long, narrow and straight, making an acute angle with the extremity of the penis. Larvae smooth, without tubercles.

(b) The *albiceps* group.—Flies dominantly metallic green, sometimes bluish with a narrow black band on hind margin of abdominal segments. Both females

and males with inner and outer vertical setae. Frontal bristles of the males represented by fine hairs. Females with one pair of fronto-orbitals only, opposite ocelli. External forceps, branches rectilinear, united almost to tip, tip slightly swollen. Internal forceps, branches almost as long as branches of external forceps, slightly curved, rounded at tip. Penis short, compact; apical extremities of lateral branches of paraphallus closely applied to paraphallus. Larvae tuberculate, each tubercle surmounted with a group of short spines.

(c) The *varipes* group.—Small flies, body colour metallic green, eyes in male as wide apart as in female. Inner and outer vertical setae and frontal setae in both sexes. Fronto-orbitals more than 1 pair, usually 3.

External forceps, branches elongate, tapering towards extremity, separated for more than half their length from extremity. Internal forceps, branches elongate, as long as branches of external forceps, slightly curved, more uniform in thickness than external, tips rounded. Lateral portion of paraphallus heavily chitinated, divided almost to base of penis, each portion with prominent sickle-shaped extremity. Lateral membranous portion broad, leaf-like and long, projecting at right angles from penis. Larvae tuberculate like those of *albiceps* group.

On this evidence, particularly in view of the characters used in the separation of genera elsewhere in the CALLIPHORIDAE, it would appear that the three groups of species should be considered as belonging to three different genera, *Chrysomyia*, *Achaetandrus* and *Microcalliphora* respectively. (Miss Aubertin, in her recent paper, has relegated *Microcalliphora* to *Chrysomyia*. I agree with Malloch (1927) in considering *Microcalliphora* a valid genus.) It is clear both from larval and adult characters that the species of the *albiceps* group are more closely related to *Microcalliphora* than to the restricted genus *Chrysomyia*. It would appear then that the ultimate removal of *Achaetandrus* from *Chrysomyia*, to which it is more remotely related than is *Achaetandrus* to *Microcalliphora*, would lead to a more natural classification than that existent at the present.

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Summary.

The Australian sheep "blowfly" *Chrysomyia rufifacies*, Macq., is shown by a study of chaetotaxy and the genitalia to be distinct from *C. albiceps* with which it has been considered identical. A discussion is given of the composite genus *Chrysomyia* and the genera into which Ségué has recently divided it. The synonymy of *C. rufifacies* is given and also the distribution of *C. rufifacies*, *C. albiceps* and *C. putoria*, the three species which Patton has considered synonymous.

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MOSQUITO FAUNA BREEDING IN BROMELIADS, AT BAHIA, BRAZIL.*

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(PLATES XVII & XVIII.)

Entomologists working in the American tropics have frequently noted the variety of the mosquito fauna breeding in Bromeliads. Dyar³ mentioned at least two species of *Anopheles*, twenty species of *Culex*, and about thirty Sabethines, the larvae of which live in the water in the leaf-bases of Bromeliaceae. Peryassú⁴ listed four species of *Megarhinus* which he said restrict their breeding entirely to Bromeliaceae, or "gravatas" as they are called in Brazil. He said that larvae of *Aedes (Stegomyia) aegypti* were sometimes seen in Bromeliads and that they had been found eleven times in 1,194 collections from gravatas, made by Dr. Sylvio Cardoso, presumably in and around Rio de Janeiro.

Because gravatas have been known to harbour *A. aegypti*, considerable effort has at times been expended during yellow fever control campaigns to destroy these plants. In 1931 Dr. D. Bruce Wilson, then in charge of the yellow fever control campaign in Bahia, and Dr. Nelson C. Davis suggested to the writer that it might be worth while to investigate the mosquitos breeding in Bromeliads close to houses in that city. Accordingly, it was planned to make a large number of collections in epiphytic and terrestrial Bromeliads, and to ascertain just which species of mosquitos were present and approximately how frequently *A. aegypti* occurred. The study could not be completed on the scale originally intended because more urgent matters demanded attention. Only 21 collections were carefully bred out and the adults identified. However, since even in this small series at least one new mosquito and several new forms were found, the results are given below.

As certain of the larval forms were not yet known, it was essential, in making this study, to breed out all the adults possible. Four species of *Microculex* were obtained and one species of *Wyeomyia*. A great deal of difference was found in the relative lengths of the siphon in the various species of *Microculex* (see fig. 12). *Culex (Microculex) imitator* had a very long and slender breathing tube which identified it with the genus *Culex*. But *Culex (Microculex) pleuristriatus* was usually black in colour and had an air-tube which was relatively short, so that it might be confused, macroscopically, with *Aedes (Stegomyia) aegypti*. The adult of *Culex (Microculex) pleuristriatus* was quite distinctive from *Stegomyia*, but, as Bonne & Bonne-Wepster¹ have pointed out, the adult of *Culex (Microculex) imitator* is "a beautiful mosquito when undamaged, with thoracic markings slightly resembling those of *Aedes aegypti*." This species seems to be subject to considerable variation, during both the adult and the larval stages. Dyar & Knab once described a form, *Microculex imitator*, whose larvae had a subapical fusiform swelling on the siphon, as a separate species and proposed the name *Culex daumasturus*.

Root,⁵ in his paper on *Culex* species collected mainly in the coastal lowlands of the State of Rio de Janeiro, mentions seven species of *Microculex*. He found *Culex (Microculex) pleuristriatus* very common and noted the same variation of form in *C. (Microculex) imitator* as was discussed by Bonne & Bonne-Wepster. He

* The studies and observations on which this paper is based were conducted with the support and under the auspices of the International Health Division of the Rockefeller Foundation.

gave the name *C. (Microculex) gairus* to a species which was identical in coloration with *C. pleuristriatus* but which differed in the male hypopygium and in larval details. *C. gairus* was not found in the city of Bahia during the present study, but Dr. Nelson C. Davis brought samples of this species from Caravellas, a small sea-coast town in the southern part of this State. Some of the specimens from Caravellas were examined by Dr. Root, who confirmed their identification.

In October 1904, Bourroul² submitted as his graduation thesis at the medical school in Bahia a dissertation on the mosquitos of Brazil. In this paper, among other new forms, *Culex albipes* was described from one adult female which had been bred from a larva caught in the water of a gravata on the island of Itaparica, State of Bahia. Apparently, with the exception of an observation by Shannon,⁶ this species had not been met with since. Dyar³ said that the male and larva were unknown, and he himself listed it as perhaps belonging to the subgenus *Culex*. About sixty females and at least nine males of what appeared to be *Culex albipes* were bred out in the course of the present study. From the larva and the male hypopygium, this species appears to belong to the subgenus *Microculex*; it is therefore classified as such in this paper. The adult female agrees in most particulars with Bourroul's original description. It is not surprising that the male is unknown, since it is almost identical with *Culex (Microculex) pleuristriatus*. The larva also is very similar to that of the latter species.

TABLE I.

Species of Mosquitos bred from Larvae collected in Bromeliads, Bahia.

Name of mosquito	Number of adults bred	Percentage of total bred
<i>Culex (Microculex) pleuristriatus</i> ...	879	52.8
<i>Culex (Microculex) davisi</i>	589	35.3
<i>Culex (Microculex) albipes</i>	71	4.3
<i>Culex (Microculex) imitator</i>	3	0.2
<i>Wyeomyia oblita</i>	124	7.4
Totals ...	1,666	100.0

During the course of this study it was necessary to do some isolation breeding in order to obtain the larval skins and corresponding adults of the new forms. As a result, some larvae died before pupating and some pupae died before the adults emerged, but in all, 1,666 mosquitos were bred out from collections made in 21 Bromeliads or groups of Bromeliads in the city of Bahia. Table I shows the relative preponderances of the different species.

Records were kept of the height above ground of the Bromeliads from which the collections were taken. *Wyeomyia oblita* was not found in Bromeliads growing more than 40 or 50 feet above the ground. On the other hand, this was the commonest species in the plants growing on the ground or at the bases of trees. *Culex (Microculex) davisi* was present in large numbers in two collections, one from five and the other from eight Bromeliads, all growing at a height of more than 50 feet above ground. However, this species was also present in another collection taken from a gravata growing on the ground itself.

Records were also kept of the approximate distances from human habitations of the various Bromeliads inspected. Several groups of gravatas were within 10 yards of houses and others were more than 100 yards away. There appeared to be

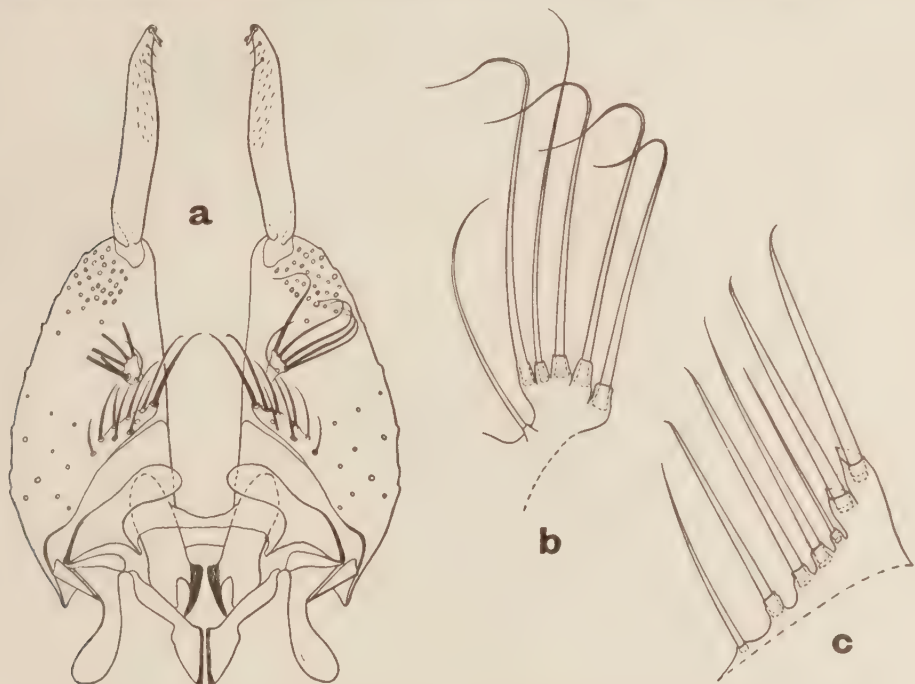


Fig. 1. *Culex (Microculex) pleuristriatus*, Theo., male hypopygium: (a) ventral view; (b) outer division of the lobe of the side-piece; (c) inner division of the lobe of the side-piece.

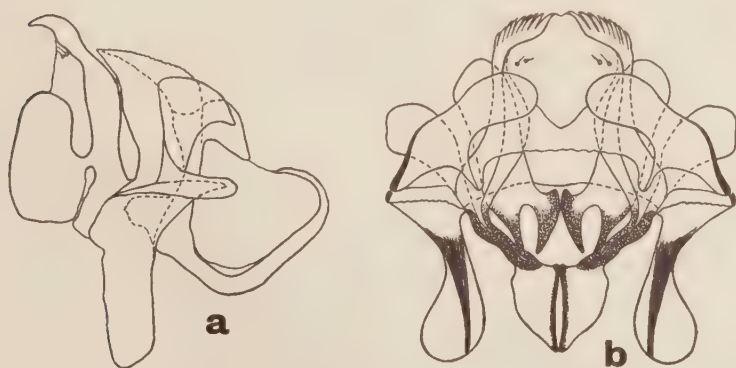


Fig. 2. *Culex (Microculex) pleuristriatus*, Theo.: (a) lateral view of mesosome; (b) ventral view of mesosome.

no association between the proximity of the trees to houses and the species present in the collections. However, the three largest collections did come from trees within 10 to 15 yards of houses.

Since *Culex (Microculex) pleuristriatus* and *C. (M.) imitator*, as well as *Wyeomyia oblita*, have been described many times, these descriptions will not be repeated here ; but diagrams of the hypopygia of these two common species of *Microculex* have

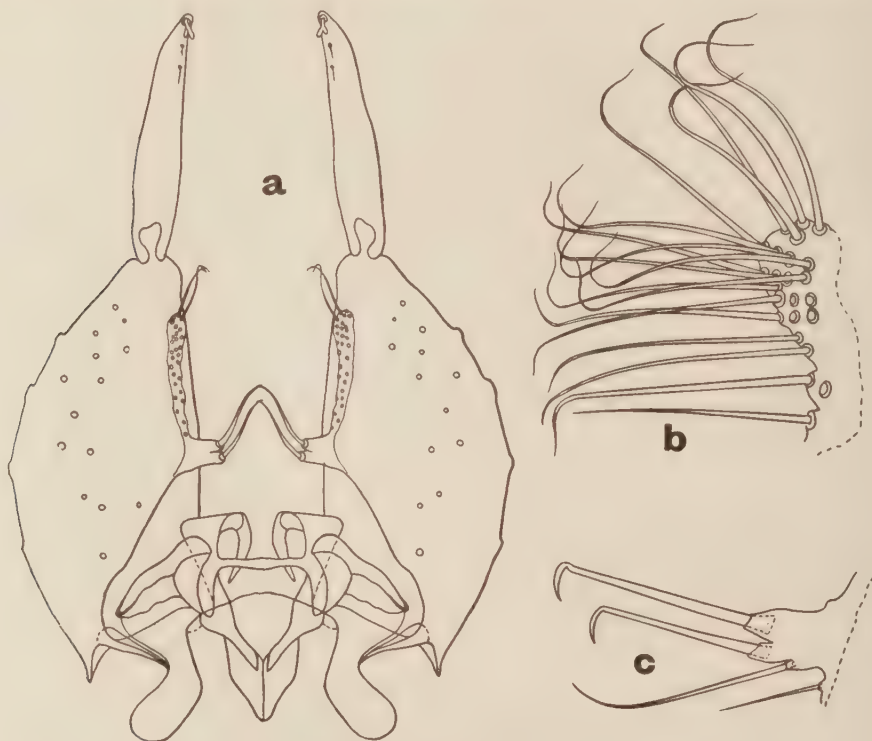


Fig. 3. *Culex (Microculex) imitator*, Theo., male hypopygium : (a) ventral view ; (b) outer division of the lobe of the side-piece ; (c) inner division of the lobe of the side-piece.

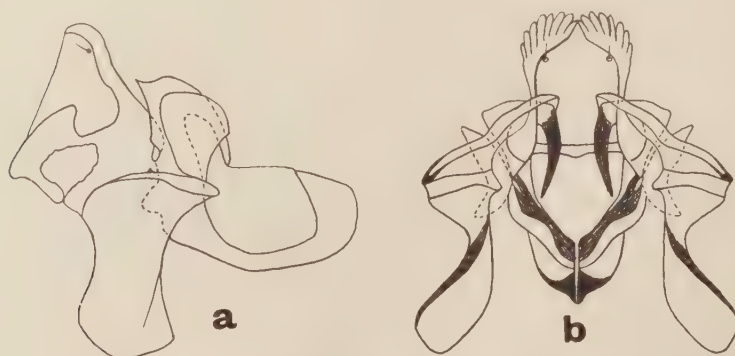


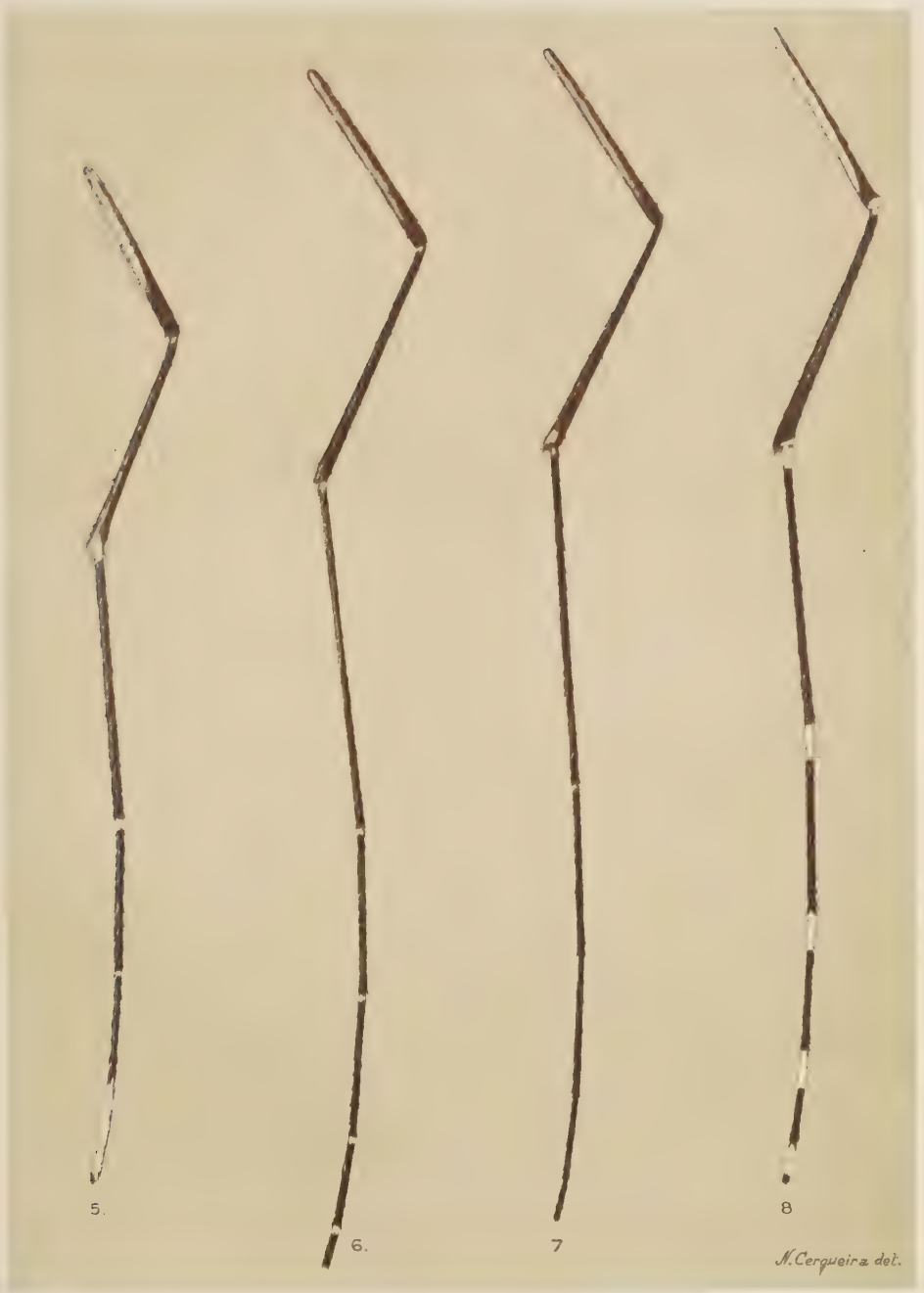
Fig. 4. *Culex (Microculex) imitator*, Theo. : (a) lateral view of mesosome ; (b) ventral view of mesosome.

been included as an aid to a discussion of the differentiating characteristics of the new forms (figs. 1-4). These features will be pointed out in the descriptions which follow.



Dorsal view of mesonotum of: 1, *Culex (Microculex) albipes*, Lutz;
2, *C. (M) pleuristriatus*, Theo.; 3, *C. (M) davis*, sp. n.; 4, *C. (M) imitator*, Theo.

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Hind legs, showing presence or absence of banding on tarsi, of:-
5, *Culex (Microculex) albipes*, Lutz; 6, *C. (M) pleuristriatus*, Theo.;
7, *C. (M) davisi*, sp. n.; 8, *C. (M) imitator*, Theo.

***Culex (Microculex) davisi*, new species.**

Adult female.—This is a small mosquito, of about the same size as *C. (M.) pleuristriatus*. The proboscis is swollen apically and is for the most part black, but it is lighter at the tip. The palpi are black, unbanded, and about one-fifth as long as the proboscis. The clypeus is rounded, brown, and nude. The occiput is black and covered with many curved cream-coloured scales and erect, forked, black bristles.

The mesonotum (Pl. xvii, fig. 3) is brown in colour with a striped appearance created by two narrow, longitudinal, bare lines. Between and lateral to these nude strips are numerous brown curved scales, yellowish hairs, and long black bristles. The scutellum is trilobed and largely nude, but it has three groups of brown scales and black bristles. The pleurae are pale and have two brown bands, much as in *C. (M.) pleuristriatus*. There are two patches of flat white sternopleural scales, such as are seen in the latter species.

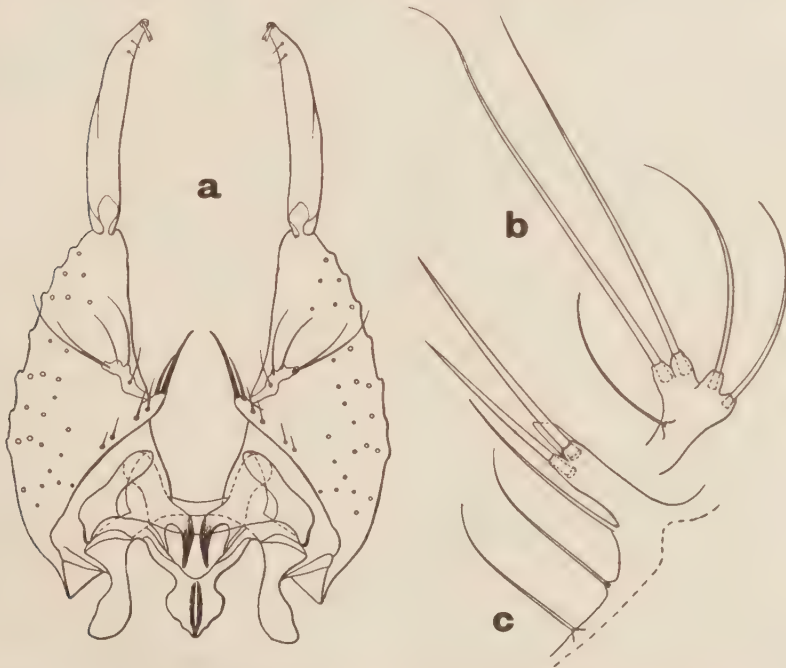


Fig. 5. *Culex (Microculex) davisi*, sp. n., male hypopygium: (a) ventral view; (b) outer division of the lobe of the side-piece; (c) inner division of the lobe of the side-piece.

The abdomen is black with basal lateral segmental patches of white scales, which sometimes extend into basal segmented bands widened at the sides. The venter is lighter in colour and faintly banded. Wing scales narrow and uniformly dark in colour.

The legs are black (Pl. xviii, fig. 7); the femora are pale beneath; the tibiae, especially the hind pair, have white apices; the tarsi are unbanded, with the exception of a narrow white ring at the base of the first tarsal segment and involving the tibio-tarsal junction.

Adult male.—The coloration of the adult male is in general the same as that of the adult female, but perhaps a shade lighter. The length of the palpi exceeds that of the proboscis by about the length of the last joint. There are narrow white basal rings on all palpal segments and in the middle of the long segment as well.

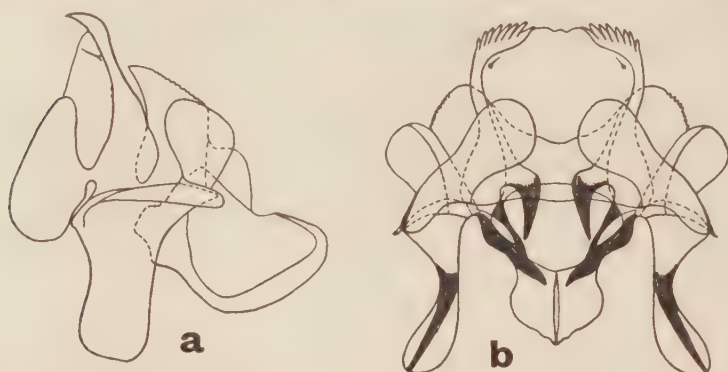


Fig. 6. *Culex (Microculex) davisi*, sp. n.: (a) lateral view of mesosoma; (b) ventral view of mesosoma.

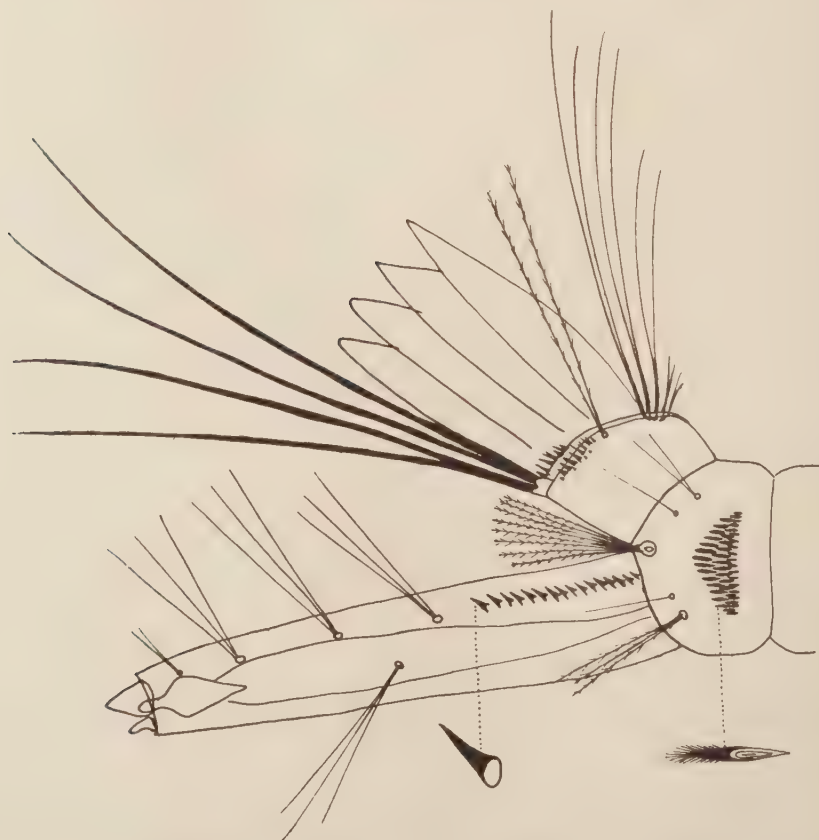


Fig. 7. *Culex (Microculex) davisi*, sp. n., larva: lateral view of terminal segments of abdomen.

Hypopygium (figs. 5, 6): The side-piece is more than twice as long as it is wide. There is no patch of long hairs on the outer surface of the side-piece just before the tip, such as is seen in *C. (M.) pleuristriatus*. The outer division of the lobe of the side-piece has two long terminal setae, two short terminal setae, and one small and fine basal seta. The inner division has two strong terminal setae and a few slender setae on the stem and at the base of the lobe. The clasper is tapered with a forked terminal spine and two small subapical papillated hairs. There is no patch of minute non-papillated hairs near the middle of the clasper such as is found in *C. (M.) pleuristriatus*. The tenth sternites are comb-like, with eight or nine teeth. The lobes of the ninth tergite are low, well separated, and each has about seven long hairs. The mesosomal plates are large and have the retrorse teeth characteristic of the subgenus *Microculex*.

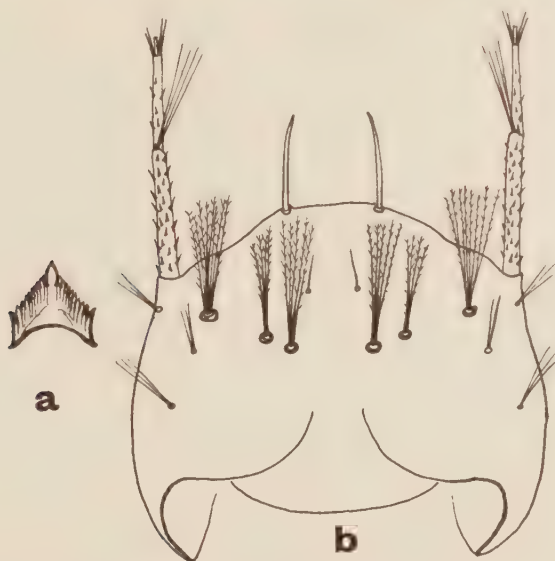


Fig. 8. *Culex (Microculex) davisi*, sp. n., larva: (a) mental plate; (b) dorsal view of head.

Larva (figs. 7, 8).

Head broad; the median frontal hairs are multiple and subplumose; the mental plate is broad and triangular. *Antennae* long, stout basally, slender terminally, and covered with numerous prominent spicules; slightly more than half way from the base is a tuft of about four fairly long hairs. *Thorax and abdomen* bare, with fairly large lateral hair-tufts. *Comb* consisting of a triangular patch of about forty barbed teeth, which are light in colour, and the barbs can be seen only under the high powers of the microscope.

Siphon about five times as long as it is broad; the length is transitional between that of *C. (M.) imitator* and that of *C. (M.) pleuristriatus* (fig. 12). The siphon is light in colour and has one small and three large posterior ventral tufts of hairs; the large tufts have three hairs each and the small subapical tuft only two. There is in addition a large lateral tuft of three or four hairs situated about midway down the air-tube. *Pecten* with twelve to sixteen unbarbed teeth in a continuous row, extending from the base about

one-third of the distance down the siphon. *Anal segment* broader than it is long, and ringed with a plate which has spines dorsally. Four large dorsal setae arise from a chitinous plaque. The ventral brush is poorly developed. There are lateral tufts of two subplumose hairs each. The anal papillae are broad and medium in length.

Type Locality: São Salvador, State of Bahia, Brazil, 1931.

This species was found in large numbers in the Bromeliads studied; over one-third of the adults which emerged were classified as *Culex (Microculex) davisi*. The adult descriptions were made from 194 representative mounted specimens, and the larval characteristics were formulated from 15 larval skins from which there had emerged adults that had been preserved and identified.

***Culex (Microculex) albipes*, Lutz, 1904.**

Adult female.—The female of this species has already been described by Lutz, in Bourroul's dissertation, from a single specimen, but as the original description is in Portuguese, it may not be amiss to redescribe the female from the specimens collected in the course of this study, in addition to listing the characters of the male and the larva, which have not before been described.

The mosquitos of this species, like the other *Microculex*, are small and appear dull brownish or black in colour until examined carefully with the microscope. The proboscis is covered with black scales and is swollen at the tip. The palpi, about one-sixth of the length of the proboscis, are mainly covered with black scales with a broad ring of white scales at the base of the second segment. The clypeus is opaque, cream-coloured, and nude. The occiput is covered with cream-coloured scales curving forward and with erect forked black bristles.

The mesonotum has the same reticulate pattern of golden scales interspersed with dark ones that is characteristic of *C. (M.) pleuristriatus* (Pl. xvii, figs. 1, 2). In addition there are three medial longitudinal bare lines between rows of golden scales. The scutellum is trilobed, with groups of golden scales and black bristles on each lobe. The pleurae are pale, with two oblique brown bands and a patch of flat white sternopleural scales exactly as in *C. (M.) pleuristriatus*.

The dorsum of the abdomen is covered with black scales, the sides with basal segmental patches of white scales. The venter is pale and faintly banded. Wing scales narrow and dark brown in colour.

The legs are black, the femora pale beneath, the tibio-tarsal junction banded with white; the tarsal segments are very narrowly ringed with white at their bases, just as in the case of *C. (M.) pleuristriatus*, except that the last two hind tarsal segments are almost entirely white (Pl. xviii, fig. 5). Frequently there are a few black scales at the apex of the fifth hind tarsal segment round the claws.

Adult male.—The adult male is indistinguishable in the gross from the adult male of *C. (M.) pleuristriatus*. The last two tarsal segments are not almost entirely white, as they are in the female *C. (M.) albipes*, but have narrow white basal rings like those of the other tarsi. The other coloration and scale distribution is the same as that of the adult female of *C. (M.) albipes*, except that the palpi have white basal rings of scales on each segment and in the middle of the long segment as well. In length, the palpi exceed the proboscis by about the length of the last joint.

Hypopygium (fig. 9): The side-piece is more than twice as long as it is wide and is convex outwardly. There is no decided patch of long hairs on the outer surface of the side-piece just before the tip, as is seen in *C. (M.) pleuristriatus*. The outer division of the lobe of the side-piece has five strong straight terminal setae all of about the same length and a small fine one at the base. (The outer division of the lobe of the side-piece of *C. (M.) pleuristriatus* has five long terminal setae, but they are usually curved at their tips.) The inner division of the lobe of the side-piece has two strong terminal setae and other spines on the stem of the lobe. This lobe is longer than that of *C. (M.) pleuristriatus*.

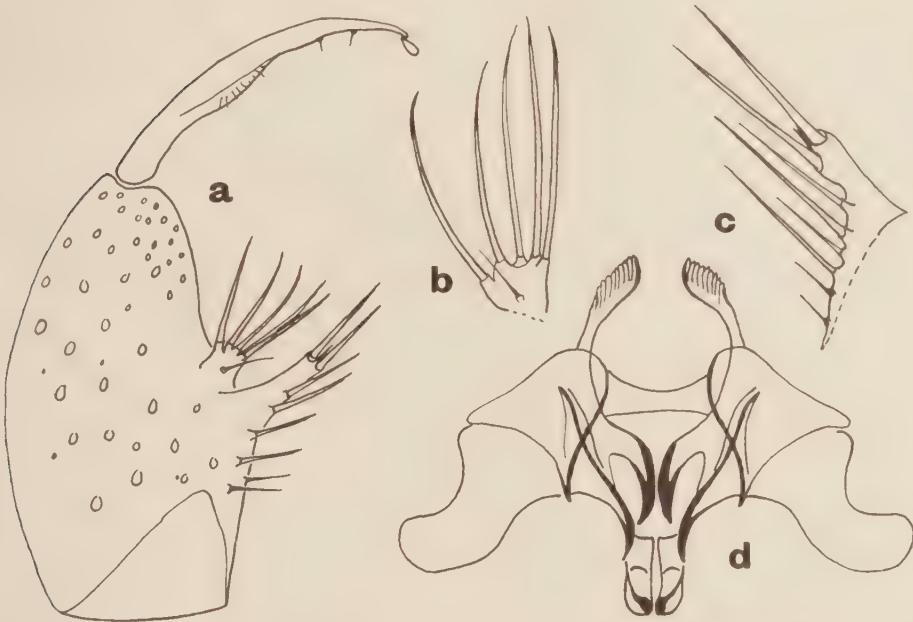


Fig. 9. *Culex (Microculex) albipes*, Lutz, male hypopygium: (a) lateral view; (b) outer division of the lobe of the side-piece; (c) inner division of the lobe of the side-piece; (d) ventral view of the mesosome.

The clasper is swollen in the middle, and this area has a patch of very minute non-papillated hairs. There are on the clasper a terminal spine and two subapical papillated hairs. The tenth sternites are comb-like, with about ten teeth. The lobes of the ninth tergite are low mounds, well separated, and with about six long hairs. The mesosomal plates are broad and have retrorse teeth, as is the case in all the other members of the subgenus *Microculex*.

Larva (figs. 10, 11, 12).

Head: The width of the head is greater than the length. The median frontal hairs are double but not subplumose and not very prominent; the mental plate is triangular. *Antennae* relatively short and slender; a few fine spicules are present on the shaft of each; and about two-thirds of the way from the base to the apex is a single fine hair. *Thorax* and *abdomen* bare with fairly large lateral hair-tufts. *Comb* consisting of a triangular patch of about twenty-five unbarbed teeth, which are dark in colour.

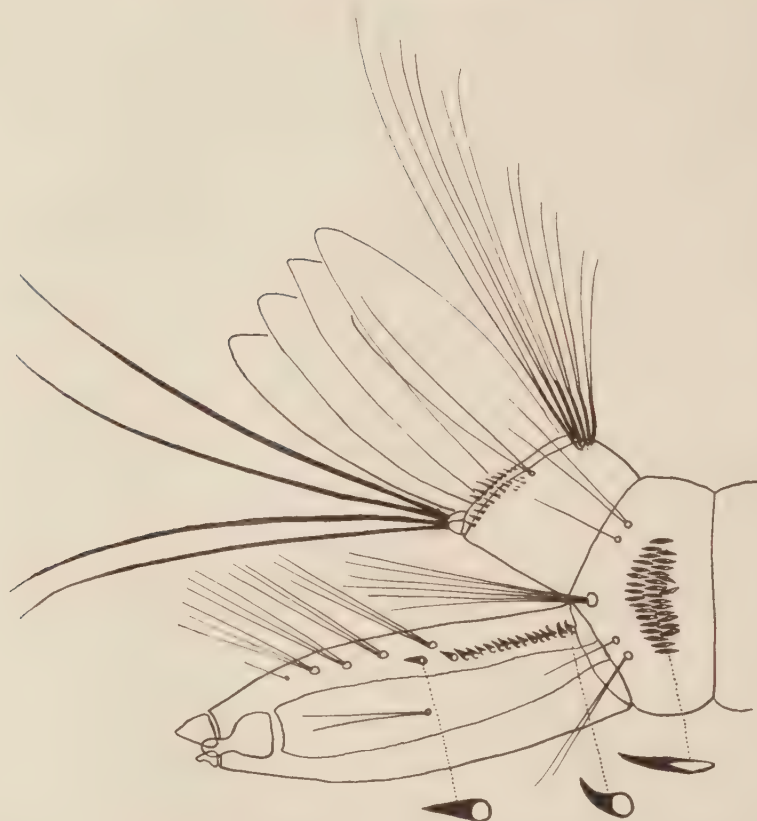


Fig. 10. *Culex (Microculex) albipes*, Lutz, larva: lateral view of terminal segments of abdomen.

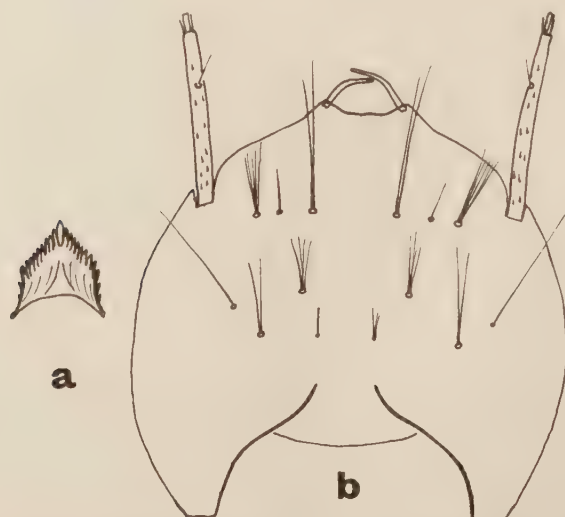


Fig. 11. *Culex (Microculex) albipes*, Lutz, larva: (a) mental plate; (b) dorsal view of head.

Siphon about three and a half times as long as the width of its base and bulging slightly in the centre. There are four large and one small posterior ventral tufts of hairs; the large tufts have three hairs each and the small subapical tuft only a single very fine hair. There is also a large lateral tuft of two or three hairs situated about midway between the apex and the base of the air-tube. *Pecten* consisting of sixteen to nineteen unbarbed teeth, sometimes in a continuous row but usually with the last tooth detached from the others towards the apex of the siphon. It is between one-third and one-half the length of the siphon. *Anal segment* broader than it is long and ringed

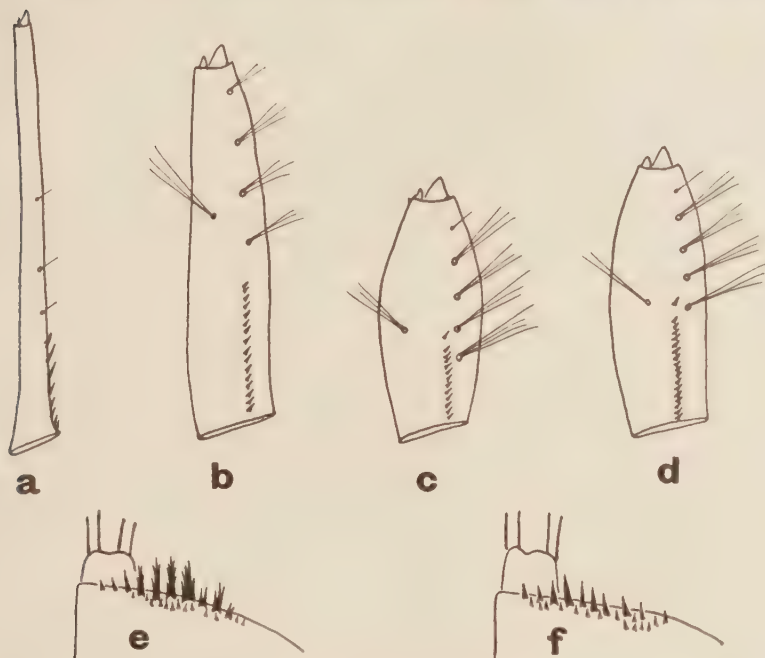


Fig. 12. Comparison of larval characters of the four *Microculex* species. Comparisons of the length of siphon of: (a) *M. imitator*; (b) *M. davisi*; (c) *M. pleuristriatus*; (d) *M. albipes*. Comparison of anal spines or teeth of: (e) *M. pleuristriatus*; (f) *M. albipes*.

with a plate which has spines dorsally. These spines or teeth are unbarbed, which distinguishes this larva from that of *C. (M.) pleuristriatus*, some of whose anal spines are very distinctly barbed (fig. 12, e). Four large dorsal setae arise from a chitinous plaque. The ventral brush is poorly developed, but is larger than that of *C. (M.) davisi*. There are lateral tufts of one or two long subplumose hairs. The anal papillae are broad, long, and rounded at the tips.

Type Locality: São Salvador, State of Bahia, Brazil, 1931.

The descriptions of adults were made from about sixty mounted female specimens and nine mounted males. Ten larval skins from which had emerged adults that had been identified were used to formulate the salient larval characteristics.

The differential characters of greatest value in separating these four species are summarised in Table II. The characters themselves can be recognized readily by reference to the diagrams.

TABLE II.

Important differential Adult and Larval Characters of four Species of Culex.

Characters	<i>Culex</i> (<i>Microculex</i>) <i>pleuristriatus</i>	<i>Culex</i> (<i>Microculex</i>) <i>albipes</i>	<i>Culex</i> (<i>Microculex</i>) <i>davisi</i>	<i>Culex</i> (<i>Microculex</i>) <i>imitator</i>
ADULT				
Banding of tarsi	Present	Present	Absent	Present
Mesonotum	Reticulate pattern of golden scales	Reticulate pattern of golden scales	Striped brown colour	Characteristic pattern of silvery white scales
Hypopygium				
Outer division of lobe of side-piece	5 long terminal setae usually curved at tip, 1 small basal seta	5 long straight terminal setae, 1 small basal seta	2 long terminal setae, 2 short terminal setae, 1 small basal seta	Row of fine setae
Inner division of lobe of side-piece	2 strong terminal setae and stout spines on base of lobe	2 strong terminal setae and stout spines on stem of lobe	2 strong terminal setae and few fine spines on stem of lobe	2 strong terminal setae and few spines on stem of lobe
Patch of hairs near tip of side-piece on outer side	Present	Absent	Absent	Absent
LARVA				
Length of siphon	Short	Short	Medium	Long
Antennae	Short, slender, few spicules on shaft	Short, slender, few spicules on shaft	Long, many large spicules on shaft	Long, slender, many fine spicules on shaft
Comb	Triangular patch, about 30 barbed teeth	Triangular patch, 20 to 25 unbarbed teeth	Triangular patch, about 40 barbed teeth	Triangular patch, about 40 unbarbed teeth
Anal spines	Present and barbed	Present and unbarbed	Present and mostly unbarbed	Present but very minute
Ventral hair-tufts or hairs on siphon	4 large tufts, 1 small tuft	4 large tufts, 1 small tuft	3 large tufts, 1 small tuft	About 3 tufts of minute hairs

Summary.

Twenty-one collections of larvae and pupae from Bromeliads, growing in trees or on the ground, were made in São Salvador, the capital of the State of Bahia, Brazil. Four species of *Microculex* and one Sabethine were bred out. Of these, one new species and certain new forms are described. The new species is called *Culex (Microculex) davisi* in honour of Dr. Nelson C. Davis, at whose suggestion this study was first undertaken. Since no *Aedes (Stegomyia) aegypti* were found, it would appear that Bromeliad breeding is probably of no importance from the standpoint of a yellow fever control campaign in this region.

Acknowledgments.

It is a pleasure and a privilege to acknowledge the help received in the preparation of this paper from Dr. Francis M. Root of the Johns Hopkins School of Hygiene and Public Health, Baltimore. Dr. Root verified the identifications of the forms which were bred out and made suggestions as to the larval and adult characters which were of greatest value for taxonomic purposes. In addition, the writer is

indebted to Mr. Nelson Cerqueira of Bahia, who made the diagrams of the hypopygia of three of the *Microculex* species and the coloured plates of the mesonota and posterior extremities.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st July and 30th September, 1933 :—

- Mr. M. AZIZ :—40 Culicidae and 25 early stages ; from Cyprus.
 Mr. H. BADOUX :—2 Parasitic Hymenoptera ; from Switzerland.
 Mr. E. BALLARD, Government Entomologist :—14 Coleoptera ; from Palestine.
 Dr. H. F. BARNES :—5 Parasitic Hymenoptera ; from England.
 Mr. H. D. BELL :—6 Diptera ; from England.
 Dr. F. S. BODENHEIMER :—155 Coleoptera ; from Palestine.
 Mr. J. J. BUCKLEY :—106 Culicidae and 80 Chironomidae ; from the British West Indies.
 Dr. P. A. BUXTON :—18 Diptera, 2 Parasitic Hymenoptera, 3 Rhynchota, 113 Orthoptera, and 3 Dermaptera ; from Nigeria.
 Mr. M. C. CHERIAN :—1 species of Mite ; from South India.
 CHIEF ENTOMOLOGIST, PRETORIA :—59 Orthoptera ; from South Africa.
 Prof. R. A. COCHRANE :—3 Coleoptera ; from Burma.
 Mr. J. H. M. COOKE :—20 Thysanura ; from England.
 Mr. G. H. CORBETT, Government Entomologist :—7 Diptera, 53 Coleoptera, 300 Parasitic Hymenoptera, 2 Formicidae, 36 Lepidoptera, 200 Isoptera, 7 Rhynchota, and 5 Orthoptera ; from Malaya.
 CORYNDON MEMORIAL MUSEUM, NAIROBI :—2 Diptera and 637 Coleoptera ; from Kenya Colony.
 Mr. A. CUTHBERTSON, Assistant Entomologist :—9 Tabanidae, 2 Asilidae and prey, 49 other Diptera, and 6 Lepidoptera ; from Southern Rhodesia.
 Mr. R. C. M. DARLING :—1,013 Orthoptera ; from the Sudan.
 Mr. W. M. DAVIES :—7 Diptera ; from Anglesey.
 DIRECTOR OF AGRICULTURE & COMMERCE, LUANDA :—1 Curculionid ; from Angola.
 DIRECTOR OF PUBLIC WORKS, LAGOS :—1,500 Isoptera ; from Nigeria.
 DIRECTOR OF VETERINARY SERVICES, KAMPALA :—37 Tabanidae ; from Uganda.
 Mr. V. H. W. DOWSON :—3 Lepidopterous early stages and 2 species of Coccidae ; from Turkey.
 Mr. S. C. DUNMORE :—6 Anobiidae ; from England.
 Mr. L. H. DUNN :—23 Streblidae ; from Panama.
 Dr. R. C. FISHER :—7 Coleoptera ; from British Honduras.
 Dr. H. J. DE FLUITER :—1 Braconid ; from Holland.
 Mr. J. L. FROGGATT :—5 Diptera, 113 Coleoptera, 5 Parasitic Hymenoptera, 8 Lepidoptera, 5 Rhynchota, and 4 Orthoptera ; from New Guinea.
 Mr. J. C. M. GARDNER, Systematic Entomologist :—35 Coleoptera and 40 Lepidoptera ; from the United Provinces, India.
 Mr. S. GARHSIDE :—9 Diptera, 41 Coleoptera, 43 Parasitic Hymenoptera, 9 Rhynchota, and 12 Planipennia ; from England.
 Mr. F. D. GOLDING, Government Entomologist :—24 Culicidae, 31 other Diptera, 69 Coleoptera, 17 Hymenoptera, 10 Lepidoptera, 4 species of Coccidae, 60 other Rhynchota, 99 Orthoptera, 2 Planipennia, and 2 Odonata ; from Nigeria.
 Mr. W. GREENWOOD :—4 Diptera, 3 Coleoptera, and 57 Lepidoptera ; from the Fiji Islands.
 Mr. D. GUNN :—8 Coleoptera ; from South Africa.
 GUTTA PERCHA & RUBBER, LTD., LONDON :—10 Coleoptera ; from Canada.
 Mr. G. H. HARDY :—12 Diptera ; from Queensland.

Mr. H. HARGREAVES, Government Entomologist :—2 Tabanidae, 2 *Glossina*, 3 *Lyperosia*, 183 other Diptera, 297 Coleoptera, 12 Parasitic Hymenoptera, 2 other Hymenoptera, 7 Lepidoptera, and 73 Rhynchota ; from Uganda.

Mr. W. V. HARRIS, Assistant Entomologist :—1 Moth and a species of Coccidae ; from Tanganyika Territory.

Mr. W. D. HINCKS :—22 Curculionidae ; from Africa.

Mr. B. M. HOBBY :—46 Parasitic Hymenoptera ; from England.

Mr. H. J. HOCKINGS :—3 Coleoptera ; from Queensland.

Mr. G. H. E. HOPKINS, Medical Entomologist :—27 Diptera, 68 Coleoptera, 43 Lepidoptera, 25 Rhynchota, 5 Planipennia, 40 Anoplura, 770 Mallophaga, 20 Ticks, and 10 Mites ; from Uganda.

Dr. W. HORN :—2,800 Coleoptera ; from various localities.

Mr. G. V. HUDSON :—2 Diptera, 100 Coleoptera, 5 Hymenoptera, and 10 Cicadidae ; from New Zealand.

IMPERIAL ENTOMOLOGIST, PUSA :—12 Cecidomyiidae ; from India.

INDEPENDENT BIOLOGICAL LABORATORIES, TEL-AVIV :—11 Diptera ; from Palestine.

INDIAN LAC RESEARCH INSTITUTE :—700 Parasitic Hymenoptera ; from Bihar, India.

Dr. H. C. JAMES :—39 Parasitic Hymenoptera ; from Kenya Colony.

Mr. H. B. JOHNSTON :—1,390 Orthoptera ; from Uganda.

Mr. C. B. R. KING, Tea Research Institute :—41 Parasitic Hymenoptera and 6 cocoons ; from Ceylon.

Mr. L. A. L. KING :—12 Diptera and 11 pupa-cases, and 31 Parasitic Hymenoptera ; from Scotland.

Mr. R. A. LEVER, Assistant Entomologist :—100 Diptera, 249 Coleoptera, and 60 early stages, 44 Parasitic Hymenoptera and 30 cocoons, 280 Formicidae, 15 Lepidoptera, 100 Isoptera, 2 species of Coccidae, 210 Spiders, 4 Scorpions, 7 Parasitic Worms, and 6 Birds ; from the Solomon Islands.

LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE :—33 Tabanidae ; from Tropical America.

Dr. R. MACKAY :—3 Coleoptera and 8 early stages ; from Tanganyika Territory.

Dr. G. MARTINAGLIA :—2 Nycteribiidae, 6 Streblidae, 15 Mites, and 2 Bats ; from South Africa.

Dr. L. MASI :—3 Parasitic Hymenoptera ; from Egypt.

Dr. D. MILLER, Cawthron Institute :—30 Rhynchota ; from New Zealand.

Mr. N. C. E. MILLER :—9 Curculionidae, 2 Rhynchota, and 76 Orthoptera ; from Malaya.

Mr. J. MUGGERIDGE, Government Entomologist :—16 Hymenoptera ; from New Zealand.

Mr. R. W. MUNGOMERY :—1 species of Coccidae ; from Queensland.

MUSEE DU CONGO BELGE, TERVUEREN :—30 Diptera, 37 Parasitic Hymenoptera, and 4 other Hymenoptera ; from the Belgian Congo.

Dr. J. G. MYERS :—6 Diptera, 28 Coleoptera, 7 Hymenoptera, 7 Lepidoptera, 1 species of Aleurodidae, 6 Planipennia, and 2 Ephemerae ; from the West Indies.

Mr. F. B. NOTLEY, Assistant Entomologist :—15 Diptera, 10 Parasitic Hymenoptera, 4 Lepidoptera, and 20 Rhynchota ; from Kenya Colony.

PACIFIC ENTOMOLOGICAL SURVEY :—14 Diptera and 124 Coleoptera ; from the Marquesas Islands.

PETERBOROUGH CO-OPERATIVE SOCIETY :—3 Ptinidae ; from England.

Mr. R. H. PHILLIPS :—3 Psychodidae and 220 Lepidoptera ; from the Fiji Islands.

Rev. O. PIEL :—59 Orthoptera ; from China.

Mr. Y. R. RAO :—4 Parasitic Hymenoptera and 10 species of Aphidae ; from Baluchistan.

Mr. P. REGNIER :—110 Parasitic Hymenoptera ; from Morocco.

Mr. A. H. RITCHIE, Entomologist :—9 Coleoptera, 142 Parasitic Hymenoptera, 2 other Hymenoptera, 8 Lepidoptera, 2 species of Coccidae and 14 other Rhynchota ; from Tanganyika Territory.

Mr. E. RIVNAY :—2 Tabanidae, 196 other Diptera and 2 larvae, 101 Coleoptera, 30 Parasitic Hymenoptera, 57 other Hymenoptera, 8 Lepidoptera, 2 species of Aphidae, 20 other Rhynchota, 40 Psocidae, 4 Orthoptera, 6 Chrysopidae, 3 Odonata, 7 Collembola, and 25 Spiders ; from Palestine.

Mr. L. L. VAN ROECHOUTD :—4 Lepidoptera ; from Belgium.

Mr. T. A. RUSSELL, Plant Pathologist :—23 Lepidoptera ; from Bermuda.

Mr. E. R. SPEYER :—1 Eulophid ; from England.

Mr. F. A. SQUIRE, Government Entomologist :—9 Siphonaptera, 40 Diptera, 25 Coleoptera, 20 Parasitic Hymenoptera, 60 other Hymenoptera, 3 species of Aphidae, 17 other Rhynchota, 10 Anoplura, 100 Ticks, 20 Mites, and 3 Millipedes ; from British Guiana.

Miss M. STEELE :—251 Diptera, 32 Coleoptera, 250 Hymenoptera, 324 Lepidoptera, 5 Isoptera, 104 Rhynchota, 22 Orthoptera, 2 Planipennia and 3 larvae, 21 Odonata larvae, 6 Trichoptera, 2 Thysanura, 90 Spiders, 10 Scorpions, and 4 Chelifers ; from the Sudan.

Mr. T. V. SUBRAMANIAM, Entomologist :—9 Diptera ; from Mysore, India.

Mr. C. F. M. SWYNNERTON :—42 Tabanidae, 47 other Diptera, 4 Coleoptera, and 7 Hymenoptera ; from England.

Mr. E. L. TAYLOR :—2 Siricidae ; from England.

Mr. A. L. TONNOIR :—4,000 Parasitic Hymenoptera ; from various localities.

Mr. W. E. WHITEHEAD :—41 Mallophaga ; from Canada.

Dr. F. ZACHER :—8 Coleoptera and 98 Parasitic Hymenoptera ; from various localities.

Mr. R. H. VAN ZWALUWENBERG :—3 Coleoptera ; from Hawaii.



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